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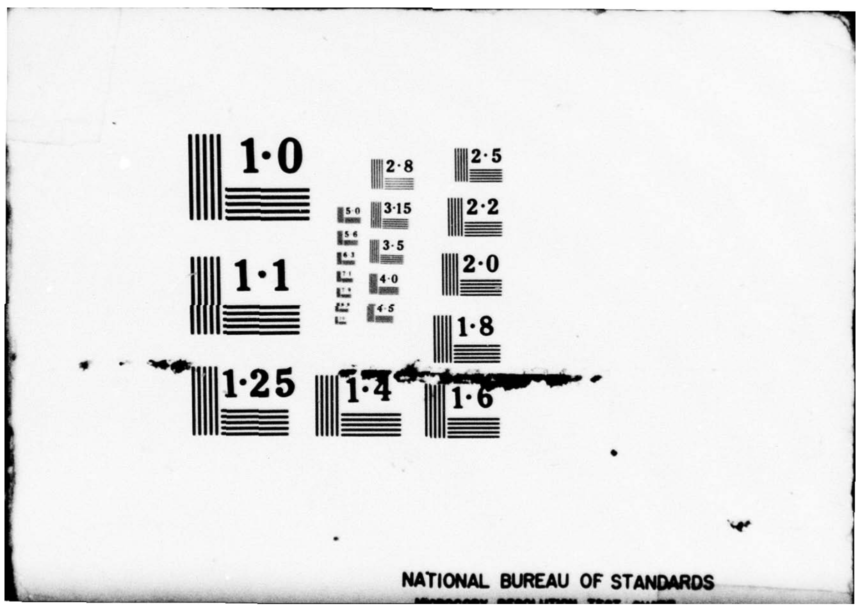
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LEVEL II

(59)

SA-ALC/MME/76-6-38-2

Government/Industry
Workshop on the

RELIABILITY OF NONDESTRUCTIVE INSPECTIONS

PROCEEDINGS

Houston, Texas
August 2-4, 1978

Prepared by The Lockheed-Georgia Company

SA-ALC/MME 76-6-38-2

Government/Industry Workshop on the RELIABILITY OF NONDESTRUCTIVE INSPECTIONS

PROCEEDINGS

Houston, Texas
August 2-4, 1978

Prepared by The Lockheed-Georgia Company

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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18. SUPPLEMENTARY NOTES

(6) Proceedings from the Government/Industry Workshop on the Reliability of Nondestructive Inspections Held at Houston, Texas on 2-4 August 1978.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Nondestructive Inspection (NDI)	Inspection Reliability
Nondestructive Testing (NDT)	Aircraft Maintenance Inspection
Nondestructive Evaluation (NDE)	Probability of Flaw Detection
Fracture Mechanics	Crack Detection Reliability

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The NDI Reliability Workshop was held in Houston, TX, on August 2-4, 1978, to present the results of the Air Force Logistics Command program, "Determination of NDI Reliability," and to provide a forum for evaluating the results and discussing approaches for NDI Reliability improvement. Attendance at the Workshop was limited to government and industry personnel whose primary interest was in nondestructive inspection, fracture mechanics, NDE equipment and quality assurance. The Workshop consisted of formal presentations, working task groups involving all attendees, and a general discussion

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forum. These Workshop Proceedings contain a transcript of the general discussion forum which presented the task group conclusions and recommendations for nondestructive inspection improvement.

FOREWORD

These Proceedings were prepared to present the findings of a three-day Workshop to examine data from a comprehensive Air Force program to determine the reliability of in-service nondestructive inspection (NDI) on aircraft structures. Workshop participants provided a number of recommendations to enhance flaw detection reliability and courses of action to implement these recommendations. A complete transcription of the eight Workshop Task Group reports which treated NDI problems dealing with Personnel, Training, Operations, Certification, Equipment, Reliability Measurement/Modeling, Fracture Mechanics/NDT Interrelationships, and data Analysis is included.

The Lockheed-Georgia Company was the prime contractor for implementation of the program to measure nondestructive inspection reliability in the Air Force and for making the arrangements for the resulting NDI Reliability Workshop. The Lockheed-Georgia Company has prepared these Workshop proceedings and has assigned it an internal control number of LG78ER0261.

The program sponsors sincerely appreciate the enthusiastic and dedicated efforts of all Workshop participants. We believe that the technical community has gained a valuable new insight into the subject as a result.

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GLOSSARY

AC	Alternating Current
AFPI 71-159	Air Force Procurement Instructions
AFPRO	Air Force Plant Representative Office
ASD	Aeronautical Systems Division
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
BASE 11	Eleventh Base visited with NDI Reliability Program
DCAS	Defense Contracts Administration Services
F/C	Fracture Critical
MIL-M-38780	Manual Technical: Nondestructive Inspection
MIL.SPECS.	Military Specifications
NASA	National Aeronautics and Space Administration
NDI	Nondestructive Inspection
NDT	Nondestructive Testing
OJT	On-the-Job Training
PMEL	Precision Measuring Equipment Laboratory
POD	Probability of Detection
RAF	Royal Air Force
S/N	Signal/Noise Ratio
SNT-TC-1A	Recommended Practice No., Qualification and Certification of NDT Personnel
SPO	Special Project Office
TA	Table of Allowances
T.O.	Technical Order
T.O. 33B-1-1	Technical Order, Nondestructive Inspection Methods
-36	Technical Manual, NDI Procedures, i.e., T.O. 1C-130A-36
410	MIL-STD-410D, NDI Personnel Qualification and Certification

WORKSHOP DIRECTORS AND STAFF

B. W. (Bernie) Boisvert	Program Monitor/USAF	SA-ALC/MMEWA
W. H. (Bill) Lewis	Program Manager/ Contractor	Lockheed-Georgia Co.
W. H. (Bill) Sproat	Program Principal Investigator	Lockheed-Georgia Co.
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J. L. (Joe) Arnold	Data Programming Consultant	Lockheed-Georgia Co.
J. M. (Jim) Hamilton	Data Programming Consultant	Lockheed-Georgia Co.
W. M. (Bill) Pless	Workshop Presentation Coordinator	Lockheed-Georgia Co.
T. C. (Tom) Cooper	Workshop Advisor & Speaker	AFML/MXA
K. (Ken) Shimmin	Data Programming Monitor/USAF	AFML/LLP
Dr. J. A. (Joe) Moyzis	Workshop Speaker	AFML/LLP

WORKSHOP
TASK GROUP LEADERS

Personnel

Roy L. Wolford	Northrop	Hawthorne, CA.
Bob Erwin	Northrop	Hawthorne, CA.
Sam I. Shelton	Ultrasonic Research & Testing Lab.	Dallas, TX.

Training

John F. Dorgan (SMS)	USAF, Travis AFB	Fairfield, CA.
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James A. Moore	Tarrant Junior College	Tyler, TX.

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Ron H. Selner	Universal Technology Corp.	Dayton, OH.
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Reliability/Measurement/Modeling

Ward J. Rummel	Martin-Marietta Aerospace	Littleton, CO.
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Fracture Mechanics/NDT Interrelationship

Mark A. Owen	ASD/ENFSF Wright-Patterson	Dayton, OH.
Edward L. Caustin	Rockwell International - LAD	El Segundo, CA.
Willard L. Castner	NASA-Johnson Space Flight Center	Houston, TX.

Data Analysis

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Don E. Pettit	Lockheed-California Co.	Burbank, CA.
R. R. Wagner	General Electric	Cincinnati, OH.

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O'Brien, Kenneth	Australian Dept. of Trans. (Airworthines)	Melbourne, Australia
O'Neil, Joe		
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WORKSHOP ATTENDEES (CONT'D)

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Pegram, James	Nuclear Power Generation Div., Babcock and Wilcox	Lynchburg, VA.
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Selner, Ronald H.	Universal Technology Corp.	Dayton, OH.
Shimmin, K.	AFML	WPAFB, OH.
Skeie, Kermit	Uresco Inc.	Cerritos, CA.
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Stellabotte, M. L.	U. S. Navy Devel. Center	Warminster, PA.
Steskal, Robert	Navy-Naval Air Systems	Washington, D.C.
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Sundareson, Sonny G.	Homelite (Textron)	Greer, S. C.
Swain, H. W.	Georgia Power Co.	Waynesboro, GA.
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Tapsfield, P.G.C.	United Kingdom Min. Defense	
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Trommeshauser, U.K. (Capt.)	Canadian Forces NDT Programme	Ottawa, Ontario, Canada
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Wagner, R. R.	General Electric	Cincinnati, OH.
Wallace, S. L. (Capt.)	SAC/USAF	Omaha, NE.
Wheeler, G. C.	General Electric	Schenectady, N. Y.
Willams, F. S.	Naval Air Development Center	Warminster, PA
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Wolford, Roy L.	Northrop	Hawthorne, CA.
Wright, Wayne A.	NASA Langley Res. Center	Hampton, VA.

Section I

INTRODUCTION

This report was prepared under the authority of Contract F41608-77-D-A021 to document the proceedings of the NDI Reliability Workshop sponsored by the U.S. Air Force Air Logistics Command and co-directed by the San Antonio Air Logistics Center and the Lockheed-Georgia Company during the period 2 - 4 August 1978. The Workshop participants included U.S. Government and industry personnel with representatives also attending from Australia, Canada and England. Initial results of the recently completed program titled "Reliability of Nondestructive Inspection on Aircraft Structures" (also known as "Have Cracks - Will Travel") formed the technical data base for the Workshop. The agenda included comprehensive presentations on the NDI Reliability Program, reports on recently developed NDI equipment included in the program for evaluation, technician screening methods, and fracture mechanics criteria applied to in-service inspections, followed by attendee participation in task group studies.

The main body of these Workshop Proceedings consists of the formal presentations and the findings and recommendations of the individual task groups presented in Sections III and V, respectively.

The need for an organized NDI program in the Air Force was conceived and implemented well over a decade ago. NDI has grown to its present state of development during the intervening period and has contributed positively toward a reduction in maintenance manhours and aircraft down time as well as improved operational safety and aircraft life extension. However, with the advent of damage tolerance design and maintenance philosophy, there is a decided need for achieving greater effectiveness in the application of nondestructive testing and the ability to measure effectiveness in the field.

Through the developing years of nondestructive testing, there was no parallel development of ability to express results of a nondestructive inspection in discrete

quantitative terms. Past efforts were devoted to development of new methods, equipment and procedures to enhance the capability to find smaller cracks. Previously, the question was; "what defects can be found?" Now we must ask; "what defects might remain undetected?" This requirement led to the initiation by the Air Force Logistics Command of the "Reliability of NDI on Aircraft Structures" program to determine the effectiveness of current NDI to detect various size in-service defects in aircraft structure under existing field and depot conditions.

The Reliability of NDI on Aircraft Structures program, which encompassed a span of approximately four years, included a planning stage, briefings, preparation of a detailed test plan, acquisition and inspection of cracked samples, development of NDI procedures and data acquisition forms. After a dry run at Wright-Patterson Air Force Base to demonstrate the entire program operation, the field data acquisition phase was conducted from October 1975 through January 1978. The data acquisition was accomplished at 21 Air Force Bases (5 Air Logistics Centers and 4 bases each from the Military Airlift Command, Tactical Air Command, Strategic Air Command, and the Air Training Command) using 298 NDI technicians to perform a total of 777 inspection tasks. After the data acquisition was complete, the structure samples were subjected to a teardown inspection to provide baseline data (crack) confirmation. Preliminary program results were combined into a data package for use by attendees at the NDI Reliability Workshop. The NDI Reliability Program data results and the presentations on August 2, 1978 describing the Reliability Program, constituted the technical basis for the NDI Reliability Workshop.

The purpose of the Workshop was to present the overall results of the NDI Reliability Program and elicit the frank comments and recommendations from attendees regarding future direction for improvement in NDI reliability.

The Workshop was felt to be a logical extension of the "Reliability of NDI on Aircraft Structures" Program and an excellent means of rapidly disseminating the initial

results of this comprehensive program which measured the actual capability of NDI to detect service-induced flaws in aircraft structure under a maintenance environment. A workshop atmosphere also permitted a free exchange of ideas and information between industry and the Air Force which provided a basis for developing new approaches for improving NDI capability and for a more compatible and interdependent relationship between fracture mechanics and NDI technology.

Section II
WORKSHOP FORMAT

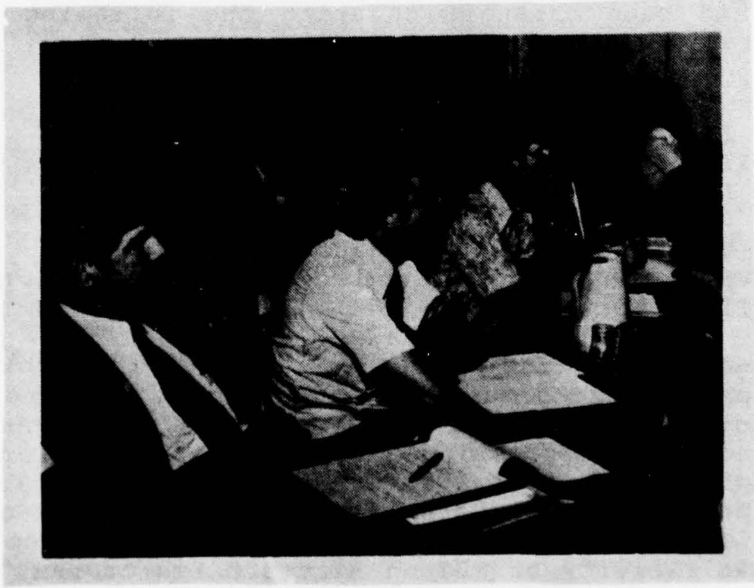
The NDI Reliability workshop was organized to provide a systematic medium for the effective interchange of information and experience. The complete Workshop agenda is included as Figure 1. The first day of the workshop consisted of a series of presentations detailing the complete program titled "Reliability of Nondestructive Inspection on Aircraft Structures". The afternoon session included presentations on the results of evaluations of NDI equipment improvements such as the automatic eddy current bolt-hole equipment and an ultrasonic scanning device for field use which were included in the NDI Reliability Program. A complete description of the NDI Reliability Program with all results is contained in Report No. SA-ALC/MME 76-6-38-1. A summary of presentations made during the first day of the Workshop, including slides, is given in Section III.

The second day was devoted to attendee participation in Task Groups of their preference. Eight separate Task Groups had been arranged covering the following areas of interest.

I	Personnel
II	Training
III	Operations
IV	Certification
V	Equipment
VI	Reliability Measurement/Modeling
VII	Fracture Mechanics/NDI Interrelationship
VIII	Data Analysis

The intent of the Task Group concept was to enable the participant's background and experience, coupled with the resources provided through workshop data presentations and group discussions, to formulate decisions for efficient upgrading of NDI. The guidelines provided the participants were products of both prior studies on NDE Reliability and the Air Force Logistics Command program, "Reliability of NDI on Aircraft Sturctures." Each one no doubt had additional subjects in mind which lent themselves to the problem areas and were encouraged to submit them to their group for consideration and inclusion in their recommendations.

GENERAL SESSION AT THE WORKSHOP



KEEN INTEREST SHOWN IN PRESENTATIONS

Government/Industry Workshop on NDI Reliability
August 2 - 4, 1978
Shamrock Hilton Hotel
Houston, Texas

AGENDA

Wednesday, August 2, 1978		8:30 a.m. to 5:00 p.m. Embassy room
8:30 a.m.	Welcome and Introduction to Workshop	B. W. Boisvert, Air Force Logistics Command W. H. Lewis Lockheed-Georgia Company
8:45 a.m.	Background and Purpose of Program	B. W. Boisvert
9:15 a.m.	Approach to Data Collection	
	History	W. H. Lewis
	Samples	W. H. Sproat, Lockheed-Georgia Company
	Data Collection	B. D. Dodd, Lockheed-Georgia Company
10:15 a.m.	Break	
10:45 a.m.	Teardown Results	W. H. Sproat
	Overall Program Results	W. H. Lewis
NOON	Lunch (Open)	
1:30 p.m.	Program Additions	B. W. Boisvert
	Automatic Eddy Current	B. W. Boisvert,
	Ultrasonic "Roto Scanner"	T. D. Cooper, Air Force Materials Laboratory
	Technician Screening Samples	J. A. Moyzis, Air Force Materials Laboratory
2:15 p.m.	Analysis of Program Results	W. H. Sproat
3:00 p.m.	Break	
3:30 p.m.	Fracture Mechanics Rqmnts. Vs. Existing Capability	T. D. Cooper
	AFML Plans	J. A. Moyzis
5:30 - 7:30 p.m.	Social Gathering - Cash Bar	

Figure 1. WORKSHOP AGENDA (Sheet 1 of 2)

WORKSHOP AGENDA (CONT'D)

Thursday, August 3, 1978 — 8:30 a.m. to 9:45 a.m., Embassy room

8:30 a.m.	Task Group Organization	T. D. Cooper
9:00 a.m.	Familiarization with Available Computer	K. D. Shimmin, Air Force Materials Laboratory
9:30 a.m.	Break	
10:00 a.m.	Task Groups (Session I)	**Location**
	I. Personnel	Walnut
	II. Training	Belvedere A
	III. Operations	Boardroom
	IV. Certification	Venetian
	V. Equipment	Castilian C
	VI. Reliability Measurement/ Modeling	Normandy A
	VII. Fracture Mechanics/NDI Interrelationship	Normandy B
	VIII. Data Analysis	Castilian A
12:30 p.m.	Workshop Luncheon	Embassy Room
	Luncheon Speaker	C. F. Tiffany, Engineering Consultant, Aeronautical Systems Division, Air Force Systems Command
1:45 p.m.	Task Groups Resume (Same Location, Session II)	
3:45 p.m.	Break	
4:00 p.m.	Task Groups Resume until Completion (Same Location, Session III)	

Friday, August 4, 1978 — 8:30 a.m. to 2:00 p.m., Castilian Room

8:30 a.m.	Task Group Reports and Discussion	Task Group Leaders
10:30 a.m.	Break	
11:00 a.m.	Task Group Reports (Cont'd)	Task Group Leaders
1:00 p.m.	Concluding Summary	B. W. Boisvert

Figure 1. WORKSHOP AGENDA (Sheet 2 of 2)

The central question asked in each Task Group was: What can be done now to improve NDI effectiveness?

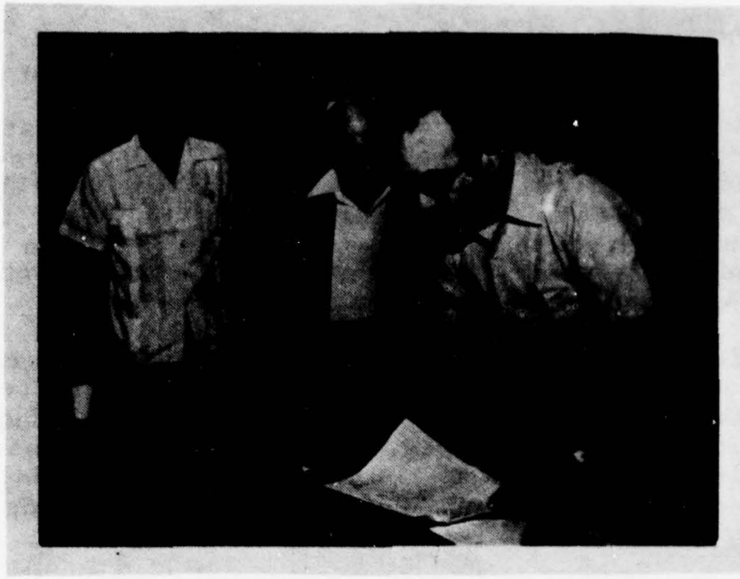
Each Workshop participant was assigned to at least two different Task Groups, based on his preference and professional interest. The opportunity was available for the attendee to participate in as many as three task groups, depending on his interests and the contributions he wished to make to the workshop objectives.

Mr. Charles F. Tiffany, Engineering Advisor for the USAF Aeronautical Systems Division, Wright-Patterson AFB, Dayton, Ohio, was the speaker for the luncheon held during the second day. Mr. Tiffany presented a talk titled "The Role of Inspections in the Maintenance of Aircraft Safety" which defined the needs and challenges for NDI.

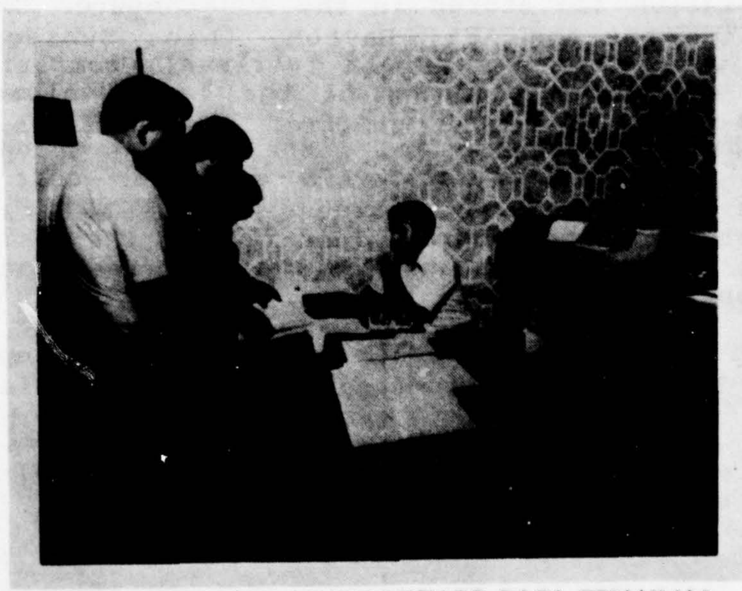
All of the data collected during the conduct of the NDI Reliability Program had been previously formatted for computerization and stored in the ASD Computer Center at Wright-Patterson AFB, Dayton, Ohio. Subsequent programs were written for data retrieval, comparison, analysis and curve plotting of the large volume of collected data. A remote computer terminal was installed at the Workshop and connected via telephone lines to the computer at WPAFB in order that the attendees could have rapid access to the NDI reliability data from the program. This feature was designed to assist in discussions and forming recommendations in the various Task Groups.

The third day of the Workshop was devoted to reports from the Task Groups, recommendations and open discussion.

A complete transcription of the third day's activity is included in this Workshop Proceeding.



WORKSHOP STAFF MAKING TASK GROUP ASSIGNMENTS



COMPUTER STAFF AT WORKSHOP DATA TERMINAL

Section III

WORKSHOP PRESENTATIONS

BACKGROUND AND PURPOSE OF PROGRAM
Bernie W. Boisvert
San Antonio ALC

APPROACH TO DATA COLLECTION - HISTORY
William H. Lewis
Lockheed-Georgia Company

APPROACH TO DATA COLLECTION - SAMPLES
William H. Sproat
Lockheed-Georgia Company

APPROACH TO DATA COLLECTION - DATA COLLECTION
Bruce Dodd
Lockheed-Georgia Company

TEARDOWN RESULTS
William H. Sproat
Lockheed-Georgia Company

OVERALL PROGRAM RESULTS
William H. Lewis
Lockheed-Georgia Company

PROGRAM ADDITIONS - AUTOMATIC EDDY CURRENT
Bernie W. Boisvert
San Antonio ALC

PROGRAM ADDITIONS - ULTRASONIC "ROTO-SCANNER"
Tom D. Cooper
Air Force Materials Laboratory

PROGRAM ADDITIONS - TECHNICIAN SCREENING SAMPLES
Dr. J. A. Moyzis
Air Force Materials Laboratory

ANALYSIS-OF PROGRAM RESULTS
William H. Sproat
Lockheed-Georgia Company

Section III

WORKSHOP PRESENTATIONS (CONT"D)

FRACTURE MECHANICS REQUIREMENTS VERSUS EXISTING NDI CAPABILITY

Tom D. Cooper
Air Force Materials Laboratory

FAMILIARIZATION WITH AVAILABLE COMPUTER

K. D. Shimmin
Air Force Materials Laboratory

Workshop Presentations

Introduction

The remainder of this Section contains the prepared text for most of the formal presentations made during the first day and second morning of the Workshop. These are listed in the preceding Agenda. Individual speakers had the liberty of deviating from the prepared text; hence, the text does not necessarily represent a verbatim transcript of each talk. Additionally, several speakers preferred to talk extemporaneously from presentation material supplied by themselves and a prepared text is therefore, not available for incorporation in this Section.

BACKGROUND AND PURPOSE OF PROGRAM
SLIDE A1

Good morning, gentlemen. My name is Bernie Boisvert and in this first talk of the Workshop agenda I'm going to give you a brief overview of the Air Force NDI Reliability Measurement Program that forms the technical basis for all of the Workshop activity. This program, officially titled Reliability Of Nondestructive Inspection On Aircraft Structures and unofficially known as "Have Cracks Will Travel", is now being completed by the Contractor, the Lockheed-Georgia Company of Marietta, Georgia. The program was sponsored primarily by the Air Force Logistics Command with some guidance and secondary support from the Air Force Materials Laboratory. Mr. Bill Lewis was the Lockheed Program Manager; Mr. Bill Sproat was the Program Principal Engineer and Mr. Bruce Dodd was the Program Engineer in the field who remained with this program throughout its data acquisition phase. During the day these gentlemen will bring you some pertinent details concerning the program and discuss the results and analyses conducted to date. Other speakers from the Air Force will discuss several related topics and Air Force Materials Laboratory additions to the program. From this initial presentation this morning I will give you a brief summary of the program, discuss some of the background that led to the program to give you, I hope, a clear understanding of the program purpose, the approach we took to

achieve that purpose, and to point out some of the major things the results seem to be telling us.

SLIDE A2

Nondestructive inspection has been used in the Air Force now for about a dozen years. During that time we have made significant progress in procuring and distributing equipment, training technicians and providing detailed Technical Order manuals on NDI applications. Because of this progress, there have been many examples of reduced maintenance manhours and reduced aircraft down-time through the application of both base and field level NDI. We are all very proud of our achievement and believe that we have the best program possible. In the past, however, and up to now we really didn't have a measure of its effectiveness.

SLIDE A3

Inspection requirements can vary widely according to the type of aircraft. Our present NDI approach in the Air Force is to isolate a specific problem area on a single component and ask a technician to inspect it. Under these conditions, chances of finding a small defect, if one exists, is usually very good. However, we are now finding that some of our newer aircraft require inspections of large, relatively gross areas of many components. The probability that the NDI technician will find isolated small defects during the NDI of numerous areas has until this time, been virtually unknown. The problem is somewhat analogous to finding a needle in a haystack when we're not sure if this haystack has a needle in it; but if it does, it's mandatory that we find it.

SLIDE A4

Data on the reliability and sensitivity of NDI has up to now only been developed for particular production line conditions. Since the advent of damage tolerant design philosophy under the MILSTD-1530 family of specifications, the Air Force has been requiring contractors of all new programs to demonstrate the capability of their production inspection processes. To

insure that no flaws larger than those determined safe by fracture mechanics technology will be present in the structure when it enters service, flaw detection curves similar to these have been generated by various manufacturers under production line conditions in their plants. The conditions under which inspections are normally conducted at both field and depot facilities are entirely different from the manufacturing environment. In the manufacturing facility the inspector usually looks at clean, bare, unassembled parts and he can do this in a temperature and humidity controlled shop where he can sit or stand comfortably at a bench and turn or twist the parts as necessary to get a complete inspection.

SLIDE 5A

Most inspections in the field, on the other hand, must be accomplished under the whims of the weather where the part is attached to or buried in the structure and the situation rarely permits the inspector to enjoy comfortable conditions. Not only is the method of inspection sometimes drastically changed, but the types of defects that may exist, types of equipment and personnel available, and accessibility factors are significantly altered. These conditions will certainly affect the ability to reliably detect small defects. Not only are the conditions in the field greatly different from those in a production line environment but they are vastly different from those existing in a laboratory environment. More often than not, an engineer sits in a laboratory and demonstrates NDI equipment response from a flaw or machined slot that he knows is there. The technician in the field is not fortunate enough to be blessed with this wonderful knowledge.

Hence, it is important to note that this NDI Reliability Measurement Program for the depot and field technicians is considerably different from previously conducted production NDI measurement and demonstration programs. The purpose, technical approach and results of this program certainly reflect this difference. For example, most of the NDI evaluation programs conducted to date were designed to demonstrate the reliability of selected production inspectors to detect specific size

defects (such as a 0.050 inch crack, for example). These have usually been conducted on a series of flat specimens, some containing defects, and were inspected in a production line manufacturing environment. In our program the technicians were required to inspect samples of actual built-up aircraft structure containing actual fatigue cracks and were required to inspect these in the environment and locations that they normally perform their inspections in.

SLIDE A6

The overall purpose of the AFLC NDI Reliability Measurement Program was to determine the current capabilities of NDI to detect various size in-service defects in real aircraft structure under actual existing field and depot conditions.

SLIDE A7

Our approach to accomplish this purpose was to take typical aircraft structure with known cracks to various aircraft field and depot NDI shops, and have the normally assigned personnel conduct routine nondestructive inspections. The key point here is that actual structure with service induced defects was taken to our maintenance facilities and inspected with personnel and equipment normally used to do these jobs. This approach enabled us to accurately and realistically determine the effectiveness of NDI at the operational level. Since this had never been done before, a great deal of care was taken at the onset to carefully lay out and plan a very thorough program that would provide statistically valid data on the many questions we had about our overall NDI program.

SLIDE A8

The overall program was conducted in three phases and has taken us over four years to complete. Phase I was initiated in mid 1974 and consisted of a twelve month activity to thoroughly plan all of the activities of the program. This included acquiring the many test samples of actual hardware with known service induced defects, to thoroughly inspect these samples and

catalog all of the known defects, to develop a very thorough test plan on how the data from the field were to be acquired, develop the detailed inspection procedures, design all of the forms on which the data were to be recorded, and acquire the various transportation and logistics hardware. Also included in this phase was the preparation of a number of briefings regarding the program and these included not only the detailed set of instructions for the participants and a separate and more comprehensive briefing for the local base management, but also top level briefings for commanders of each of the major participating commands to ensure their full participation and support in this program. The plans for the program were thoroughly reviewed by a panel of some of the most knowledgeable and experienced individuals from both government and industry in this area of technology. To ensure that nothing had been overlooked that would invalidate the final results of the program, once all of the planning and preparation were complete, a dry run of the data acquisition was made to iron the wrinkles out of the program. This trial dry run was conducted in the summer of 1975 at the Aeronautical Systems Division 4950th Air Base Wing at Wright Patterson Air Force Base in Dayton, Ohio. This trial dry run served two very important purposes. First it enabled us to start our data acquisition phase in the field assured that the program would run smoothly from the start; and second, it enabled a large number of Air Force scientists and engineers at Wright Patterson Air Force Base to view the data acquisition phase of the program at first hand and to make suggestions for potential improvements. Next came the series of command briefings to each of the major participating commands to assure their complete cooperation in the program and to schedule the visitations to their particular bases and, finally, the actual data acquisition began on 14 October 1975. The data acquisiton phase of the program continued uninterruped from the fall of 1975 until mid January 1978 when visitation of the last of the twenty-one scheduled bases was completed at Shaw Air Force Base in Sumter, South Carolina. At the completion of the data acquisition phase, all of the samples were returned to the contractor's facility in Marietta, Georgia for a complete teardown inspection to verify the existence of all suspected flaws in the

samples and for an accurate destructive measurement of the true size and orientation of each crack. As you can see on the slide, we are now in the final phase of our program, with the Workshop you are currently attending being one of the vehicles we plan to utilize to help disseminate the results of this program. We had hoped to be able to provide you with a copy of the final report for your use at this Workshop; however the time required to obtain all of the necessary approvals of such a comprehensive report has precluded its final release as of this date. Instead, you have been provided with a working copy of the majority of the material that will be contained in the final report. And also as you can see, not only will all of the attendees at this Workshop receive a copy of the final report once it is approved and published, but you will also be receiving a copy of the Workshop Proceedings later this year.

SLIDE A9

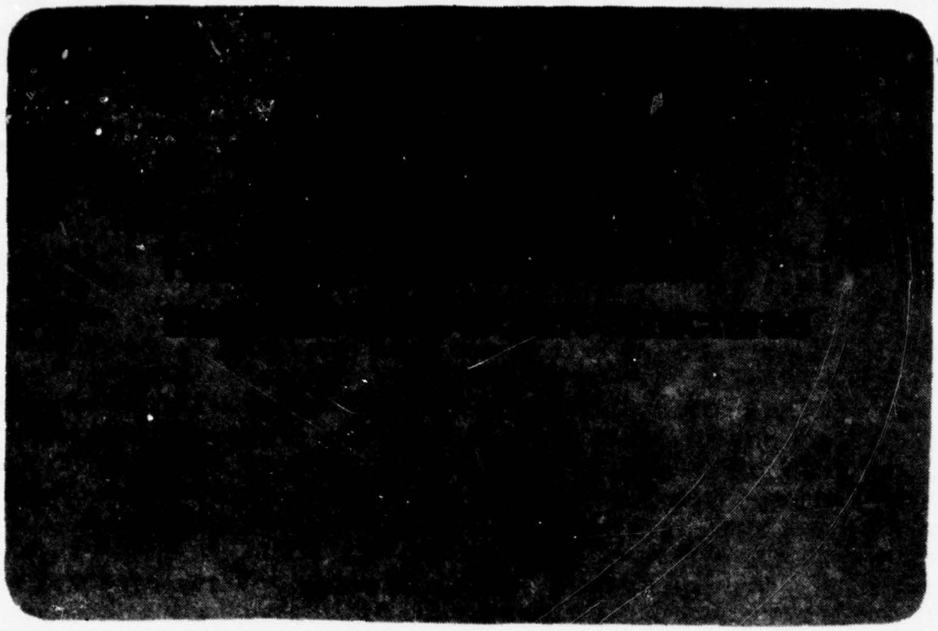
Now that you have a brief idea of what the NDI Reliability Program was all about and how it was conducted, let me point out some implications of the results, then I would like to define a few areas where the total overall NDI Program needs your help and what we hope to accomplish at this Workshop. First of all, the results tell us that the average NDI capability in the Air Force is not as good as we might desire it to be. We must now try to identify the true reasons for this and to identify the positive steps we can take to improve it. Another thing we must do is to get structural designers, structural analysts and inspection personnel all talking to each other in a compatible language based on realistic inspection requirements and capabilities. The question that you see on this slide is a very pertinent one that we want you to take very seriously. We solicit your ideas and suggestions toward improving nondestructive inspection in every area. We need your help in looking for ways to improve our NDI capability without resorting to costlier or lengthier inspection approaches. Without adopting a market basket of approaches, some of which may not really buy us anything. What approaches to improvement in NDI promise the greatest cost effectiveness? What causes and effects do you see in our data? What implications can

you see there? From your viewpoint of experience what approaches bring us the greatest benefits? Do these approaches involve personnel qualification and certification, revamping our training programs, better initial selection of and retention of our NDI personnel, developing new and improved equipment, greater sensitivities, different inspection planning?

Because of the unique contributions that can be made not only to operational NDI but also to NDI training, equipment, and to the design and serviceability of all types of hardware, we cannot overemphasize the potential importance of this program nor the importance of contributions you will have the opportunity to make during this meeting. We have right here in this room perhaps the greatest collection of experience and expertise in nondestructive inspection. We want you to bring that experience and expertise to bear on the questions we have raised. We want you to share your knowledge and experience so that collectively, we may provide the guidance and direction toward overall improvement in our NDI capability.

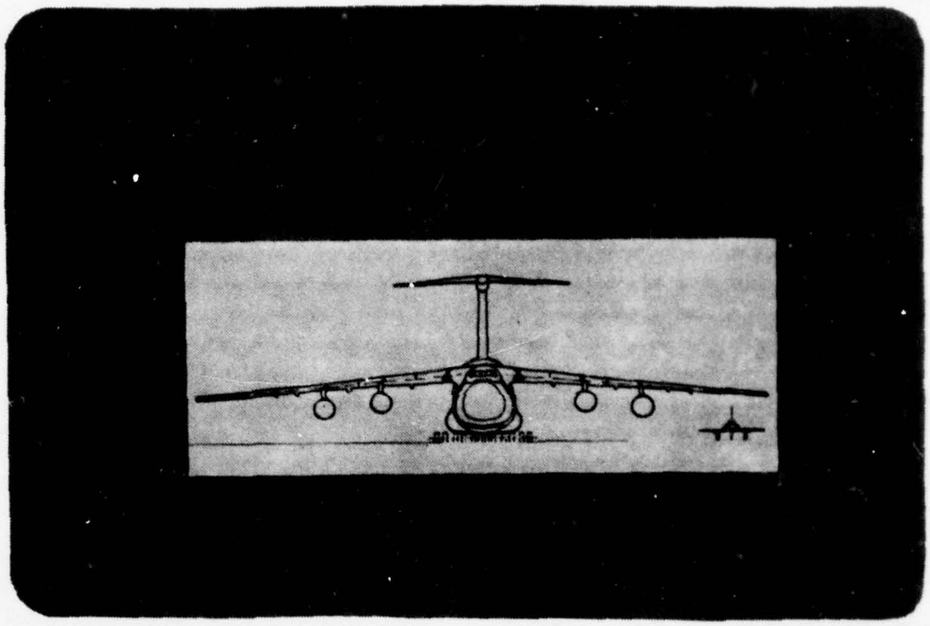
One final comment from me. We also want you to take a look at our NDI reliability program. What would you have done differently if you were going to undertake such a capability assessment program? What are the inherent limitations for applying the results of the program? Has there been anything omitted from this program that should be considered for inclusion in future programs? In other words, just how good or how useful is our program? We would like to have your opinion. Now that I hope I have given you a brief insight into the background and overall purpose of our program, I am going to let the contractor fill you in with the details of exactly how the program was conducted. First Bill Lewis will give you some of the history behind the program and an insight into the planning efforts that went into the program. Next Bill Sproat will describe the details of each of the samples that we used in the program and finally Bruce Dodd, the project engineer that accompanied the program throughout the entire data acquisition effort of over two years, will give you the details on exactly how the data were collected at all of the Air Force installations he visited. Thank you.

SLIDE A1



SLIDE A2

SLIDE A3



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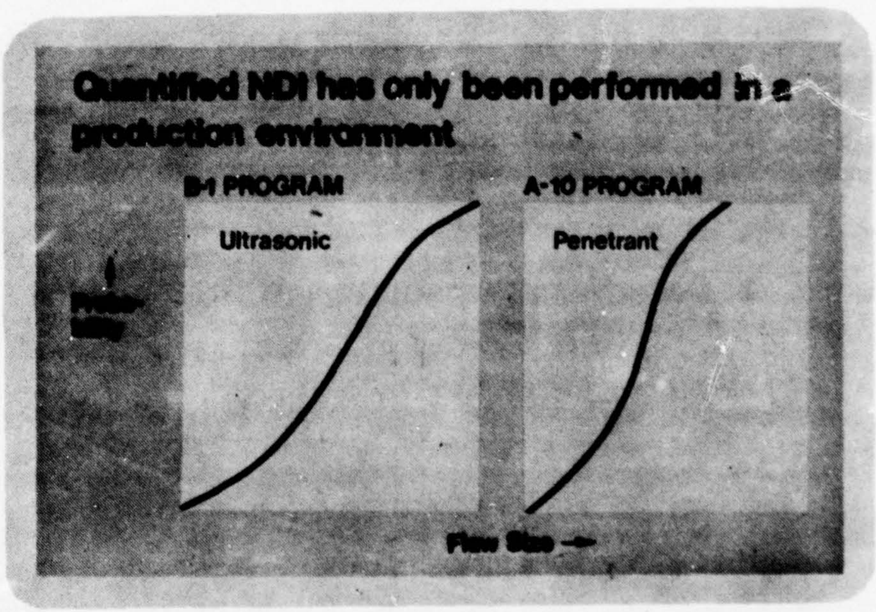

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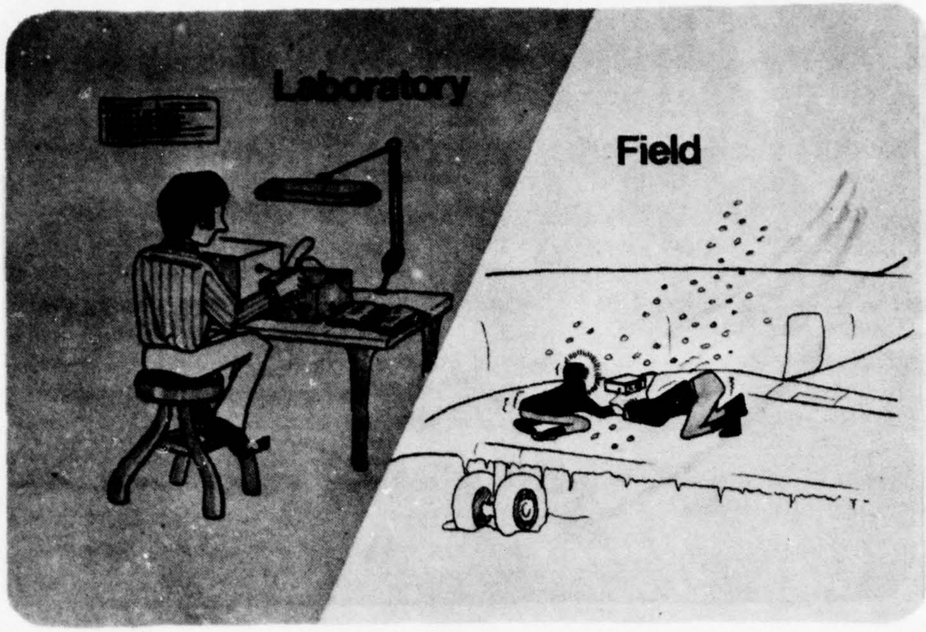
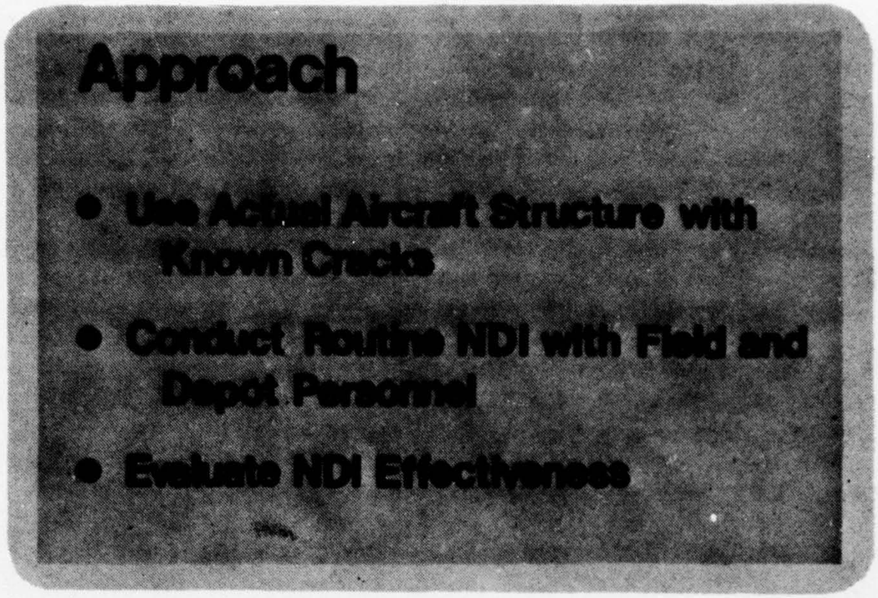


SLIDE A6

Purpose

- Determine Capabilities of Routine NDI to Detect Cracks in Structure under Field and Depot Conditions

SLIDE A7



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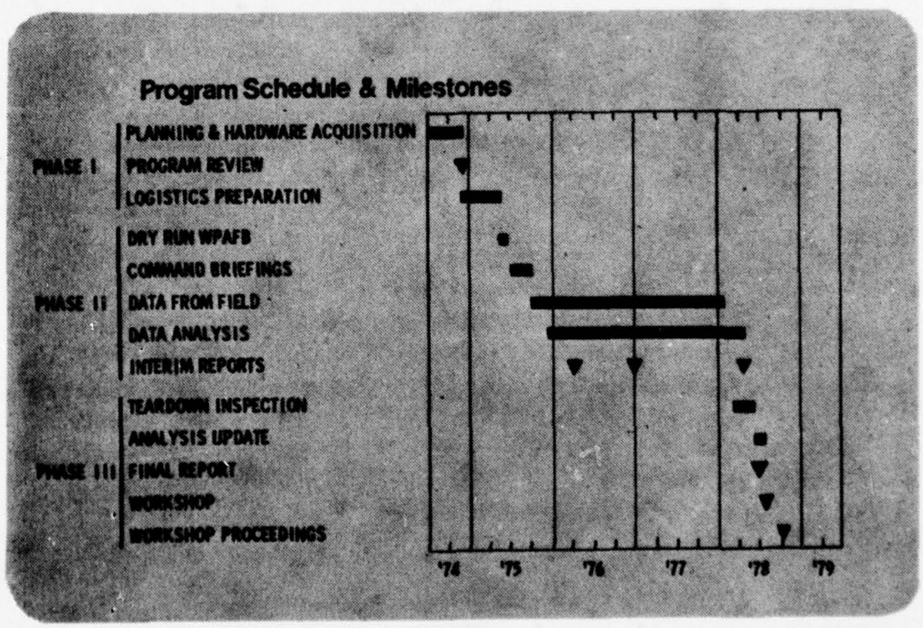
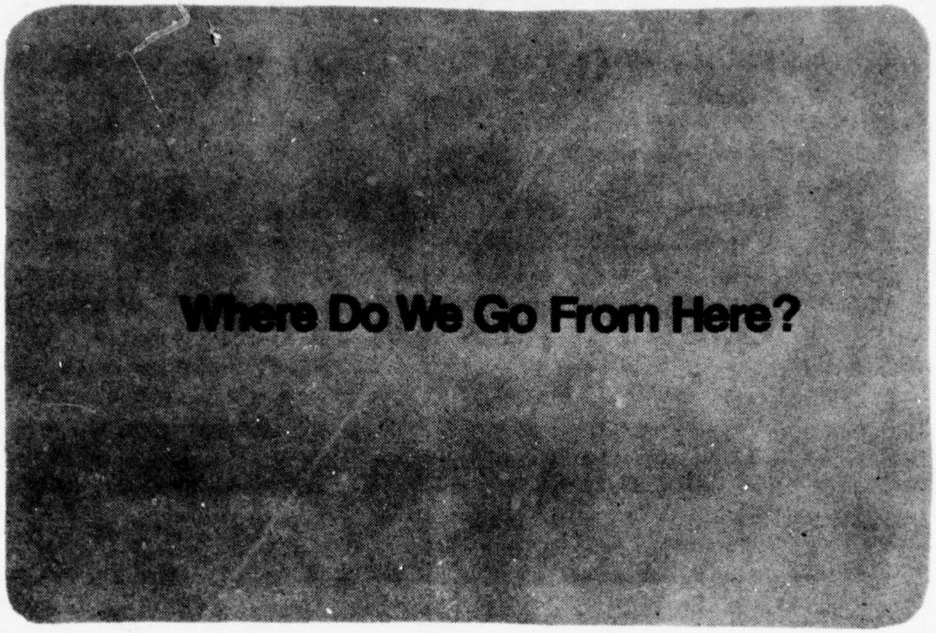


SLIDE A9



APPROACH TO DATA COLLECTION - HISTORY
SLIDE B1

Good morning. I want to offer you a brief account of some of the historical factors that shaped this NDI reliability measurement program to its final form. This program is only a part of the large body of thought and experimentation that began to take shape in the late 1960's and now after more than a decade is beginning to point us to some of the necessary remedies for achieving a much greater effectiveness in the application of nondestructive testing.

SLIDE B2

The NDT community has long been aware of the inability to express the results of a nondestructive examination in discrete quantitative terms. Hence, there have been continuous efforts to develop new methods, equipment and procedures that will provide a more quantitative measure of the defects in the material. One major factor that has been missing is the knowledge of how effective our methods and procedures really are in any particular application. Previously, NDI effectiveness was accepted mostly on the basis of what defects were actually found. In most cases it was assumed and sometimes disastrously that whenever NDT was applied to a material or a part the results gave an accurate assessment of the part's integrity. Obviously this was a mistake. What was not, of course, taken into account, probably because it was invisible or unknowable at the time, is what defects remained undetected in the part at the conclusion of the inspection. This, I submit, is the most crucial factor in an NDT examination.

SLIDE B3

To put this another way, our efforts have been seemingly directed towards what is the smallest crack we can find. How many times have you heard the same question yourself? Perhaps you have asked this question many times. How small of a crack can you find? But of course this isn't really what we want to know. We don't really care what the smallest crack is we can find. Some of our present day equipment, under the right

circumstances, has the capability of finding extremely small defects.

SLIDE B4

The question we really ought to be asking, of course, is "what is the largest crack that can be missed?" We don't ever ask this question. Perhaps that is because we realize we don't really know the answer. But this is actually what we need to know. After we have applied the latest that our technology has to offer in the inspection and examination of a part or material, what is the largest defect that remains undetected? A detected defect can either be repaired or eliminated. It is the undetected defect which remains in spite of all of our good intentions that can kill us if it gets big enough.

SLIDE B5

This is perhaps the most famous crack in modern history. An F-111 aircraft was lost while on a training mission from Nellis AFB, Nevada, in 1969. Although the aircraft only had 105 total flight hours, it experienced catastrophic failure of the wing box. The cause of the accident was determined to be a nearly one inch long flaw on the surface of the lower panel in the D6AC wing carry-through box. This flaw, which had been overlooked during production inspection, was about 90% through the entire part thickness. The light band shown here surrounding the flaw is the region of fatigue propagation which took place during the 105 flight hour life of the aircraft prior to the accident. The point that I want to illustrate is, that this inch long-flaw escaped detection during manufacturing inspection which is certainly under more ideal environmental and accessibility conditions than most maintenance inspection operations. Therefore, it can only be assumed that possibly similar type defects could be overlooked and missed during a typical maintenance inspection.

SLIDE B6

I would like to quickly point out that I am not singling out the F-111 incident; but it certainly serves to illustrate the point that rather large and seemingly obvious defects can be missed and remain undetected at the completion of a nondestructive inspection. As shown here, tool damage in a fastener hole that went undetected, caused this wing failure on an F-5 aircraft in April of 1970.

SLIDE B7

In 1973, a wing attachment lug on an F-4 aircraft failed due to an undetected fatigue crack that was missed during routine nondestructive inspection, and within six flights the adjacent wing attachment lug failed, resulting in the loss of the entire wing and, of course, the aircraft. I could continue to go on and on citing example after example using the C-5, C-130, KC-135, B-52, and many other aircraft where flaws and cracks have been missed during routine inspections and the results have been catastrophic.

SLIDE B8

I certainly don't want to leave you with the impression that aircraft inspectors are the only ones who miss cracks. Shown here is the disastruous derailment of Amtrak Train No. 40.

SLIDE B9

This detailment was attributed to the rail failure shown here, which was caused by a 14 inch long crack which had been missed in a recent rail car inspection of this particular section of track. I think it is sufficient to say that we have ample reason to question the reliability of our present day nondestructive inspections to find all of the cracks that we have to, in order to prevent structural failures.

SLIDE B10

By using fracture mechanics technology, we can predict what size defects our structures can safely tolerate and how fast those defects will grow to unsafe sizes under operational conditions in service. What we don't know is how large those defects have to be before we can be sure that we will find them during a properly conducted inspection. This was the overriding drive behind the program we have just completed for the Air Force. Under typical field and depot maintenance conditions, what size cracks in aircraft structure can be reliably found and what size cracks could be missed?

SLIDE B11

It was determined that the most direct and cost effective approach to resolve this question was to take typical aircraft structure with existing service-induced cracks to various Air Force bases and depots and have the normally assigned NDI Technicians go about conducting nondestructive inspections on these samples, using their existing equipment and procedures typical of everyday useage.

SLIDE B12

Our initial program contained two different types of aircraft structure, and we tentatively planned to conduct sample inspections at all five Air Force Logistic Command depots and six typical bases in the field. As Bernie mentioned, a critical review of the original plan for conducting the program was conducted in November of 1974 by a select Steering Committee composed of various government and industry experts. This sixteen member committee conducted a full review of past programs of this type and made some important decisions as to the approach this program should take in order to assure that the results would provide a full and valid evaluation of Air Force NDI capabilities and that the results would be not only statistically valid, but generally accepted by all concerned. This is certainly not the type of program that can be conducted every day, not even every year or so, and it was therefore extremely important to be sure that everything was right from the start.

SLIDE B13

The steering committee recommended an expansion of the types and quantity of program samples to cover a greater range of aircraft structure and an increase in the number of flaws in each size range. The number of types of samples in the program increased from two to the six shown here which typify various components of an aircraft structure which require periodic nondestructive inspection. I would like to point out that it was no small effort to obtain suitable test samples. It was, of course, necessary to provide a range of specimens that were fairly representative of aircraft structure inspected in various commands. All samples would have to contain actual fatigue cracks in a wide range of sizes. We were fortunate, in that a number of wing boxes remained from a C-130 inner wing box replacement program a few years earlier which provided many of the final structural samples. These wing boxes, which had exceeded their originally designed fatigue life contained a number of typical fatigue cracks. In addition, one of the boxes removed from a commercial C-130 had undergone considerable full-scale fatigue testing which, in fact, had generated a number of additional cracks. A number of titanium truss specimens containing a variety of fatigue cracks were available from a previously conducted C-5A engine pylon NDI reliability assessment program and we were able to utilize those in this program. With the exception of a few other components derived from some selected full-scale fatigue testing, actual aircraft structure containing service induced fatigue cracks was very difficult to come by. The Steering committee, through their own contacts, made a maximum effort to obtain what ever scrapped aircraft components were readily available during this time period that contained real life in-service fatigue cracks.

As a result, the small number of samples of KC-135 center wing structure and a number of forged fittings from a F-104 wing were obtained and included in the program. I think it is important here to note something that you may find interesting and which I think serves to further emphasize several of the points we have been

making. The KC-135 wing panel specimens that we included in our program were originally found cracked by Boeing during the KC-135 replanking program at their Wichita, Kansas facility. The cracked panels were forwarded by Boeing to the Air Force Logistics Center at Oklahoma City where the cracks were verified and the panels stored. We obtained the panels from Oklahoma City, reinspected them, and not only noted the exact location of each crack but also made an estimate of its apparent size and orientation. Structural sample specimens were then made from these panels and included in our program which toured the twenty-one Air Force installations visited. During that time, several hundred Air Force technicians inspected these panels and a number of them found the small cracks that were supposedly contained in these samples. I used the word supposedly because, as you will later see, in order to verify the true size and shape of each and every crack in our program, all of the structural samples were destructively disassembled and metallurgically examined under careful laboratory conditions. Not <u>any</u> of the KC-135 wing panels we included in our program contained a single crack! Again, these "cracks" had been found by Boeing, verified by the Air Force, and not only reverified by Lockheed, but we even measured their apparent size. Now admittedly we thought these were pretty small to begin with, most of them measuring less than .050 in length; nevertheless, we had detected what we thought were apparent fatigue cracks. In reality most of them turned out to be either scratches, gouges, or pits in and around the fastener holes that were produced by disassembly and subsequent cleaning and etching operations prior to their initial inspection. But I think this does serve to point out part of our reliability problem with nondestructive inspection.

SLIDE B14

Shown here are the four basic methods of nondestructive inspection that we evaluated in our program. The one method that is conspicious by its absence in the program is the use of magnetic particle. There were several reasons for this and after thorough evaluation the steering committee determined that it was next to impossible, during the time frame that we had, to obtain

a large enough quantity of steel samples with a range of crack sizes necessary to include in our program. Since most of the high strength steels used in the aircraft industry do not tolerate large cracks, most flawed steel parts fail before the flaw has grown to a sufficient size to enable easy detection.

SLIDE B15

Finally, because of the large amount of variation between the different commands and their differences in applying NDI, not only between the commands but between *various bases within each command*, the Steering Committee determined that a broader sampling of field installations was necessary. Consequently the scope of the program was enlarged to include not only all five Air Force depots but a minimum of four bases within each of the four major operating commands of TAC, MAC, SAC, and the Air Training Command.

SLIDE B16

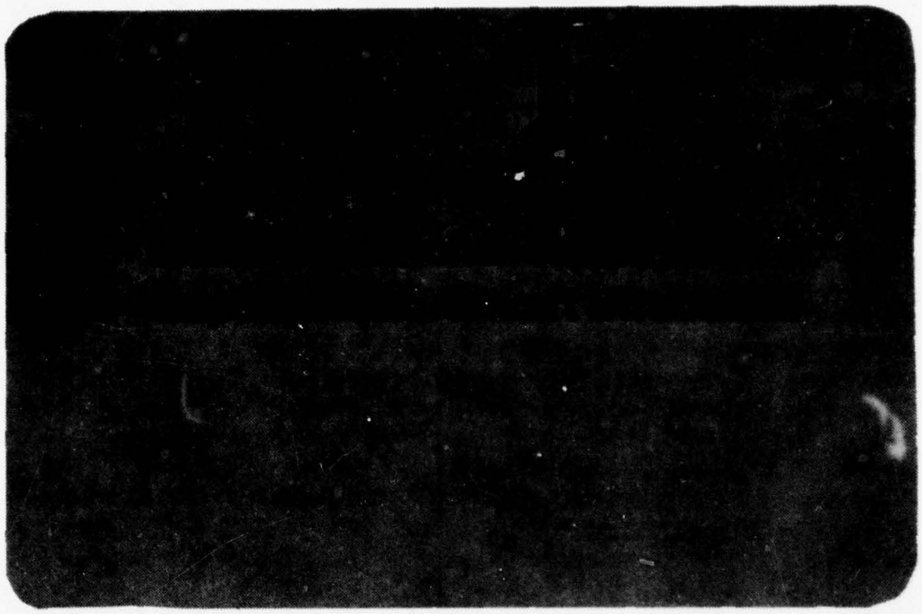
Once the steering committee had approved the overall program approach, the detail preparation for acquiring the data began in earnest. This included not only assembling and preparing all of the stuructural samples and cataloging their *crack locations and apparent* sizes, but developing detailed straight-forward NDI procedures identical to those that the technicians were accustomed to using in his Tech Order, for his use in inspecting and hopefully detecting the cracks in the samples. We also designed a series of data collection forms that would enable us to not only record whether or not the inspecor found the cracks in the samples and which ones he missed, but forms were also designed to record as many of the variables as we could that were associated with our data collection.

These will be discussed in some detail with you later this morning so that you will have an insight into the vast amount of data that we actually have collected and is currently stored in the computer files at the Aeronautical Systems Division Computer Center at Wright-Patterson Air Force Base.

SLIDE B17

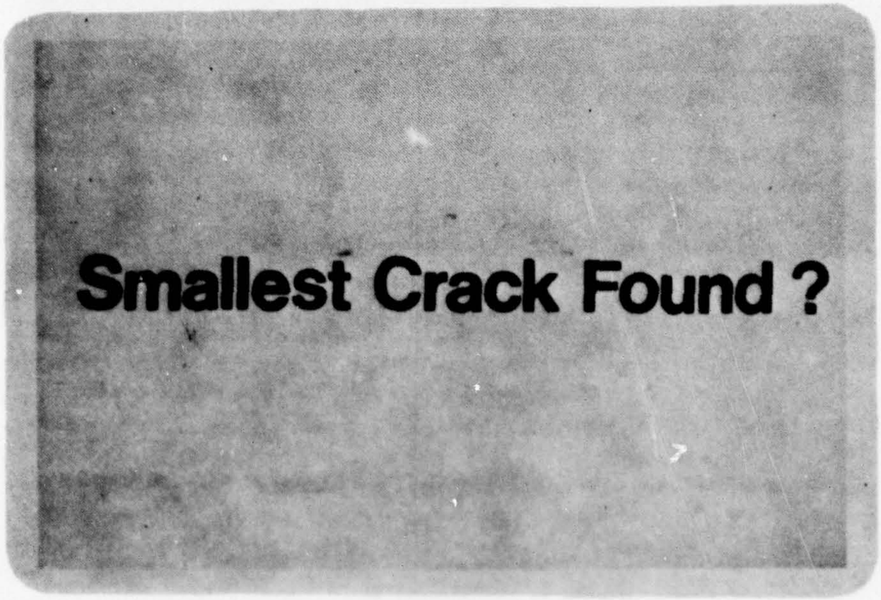
All in all, the planning phase of our program took just about a year to complete and resulted in a very complete and comprehensive Program Test Plan. The Phase I Test Plan Report, of which we have several copies here, is available through the government information exchange and the Defense Documentation Center data systems. It contains all of the details about exactly how the program was conducted, including samples of the data forms that we used to collect the data, detailed descriptions of each of the specimens used, the schedule for all of the installations visited, a copy of the NDI manual containing the detailed inspection procedures developed for the program that the technicains used to inspect the specimens and a copy of the orientation briefing that was given to each technician that participated in the program. Finally, after all of the planning was completd, as Bernie mentioned, we conducted briefings at the headquarters of each of the major participating commands, not only to brief them on exactly what the program was about and why it was being conducted, but to insure that we had the full cooperation of each of the participating commands to permit us on their base and supply the manhours for the technicians to participate in our program. Now before we discuss the data collection phase of the program, I think it is important that each of you get fixed in your mind exactly what each of the specimens we have in the program were and exactly what the NDI inspections consisted of and the detailed inspection procedures that were used. Bill Sproat will now give you a brief rundown on each of these.

SLIDE B1



SLIDE B2

SLIDE B3



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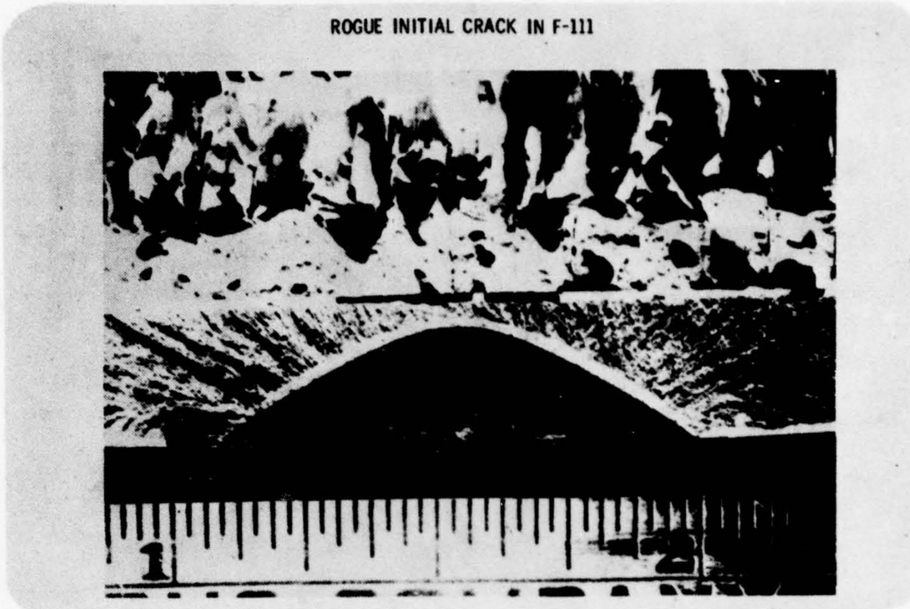
SLIDE B5



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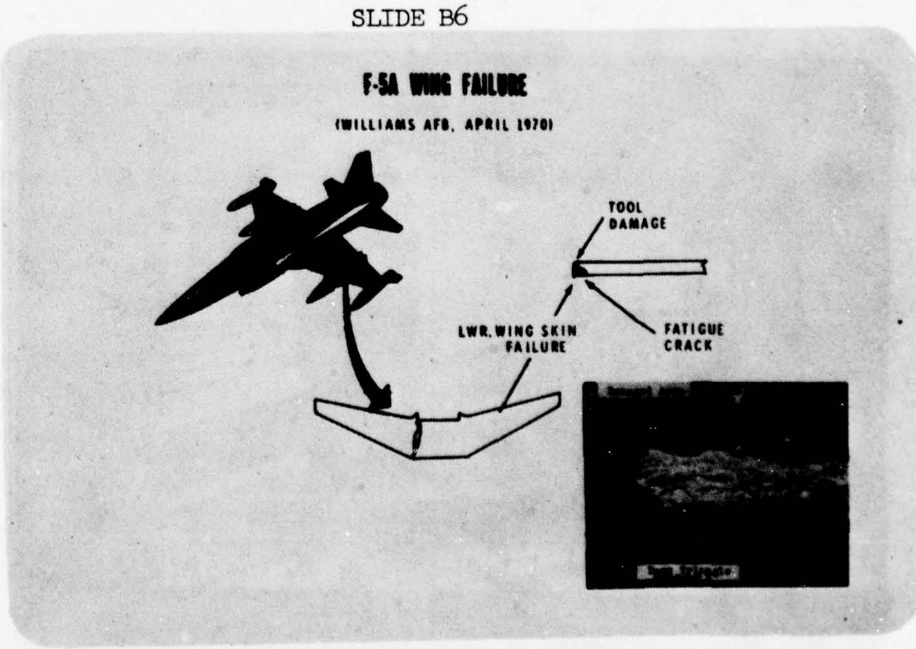

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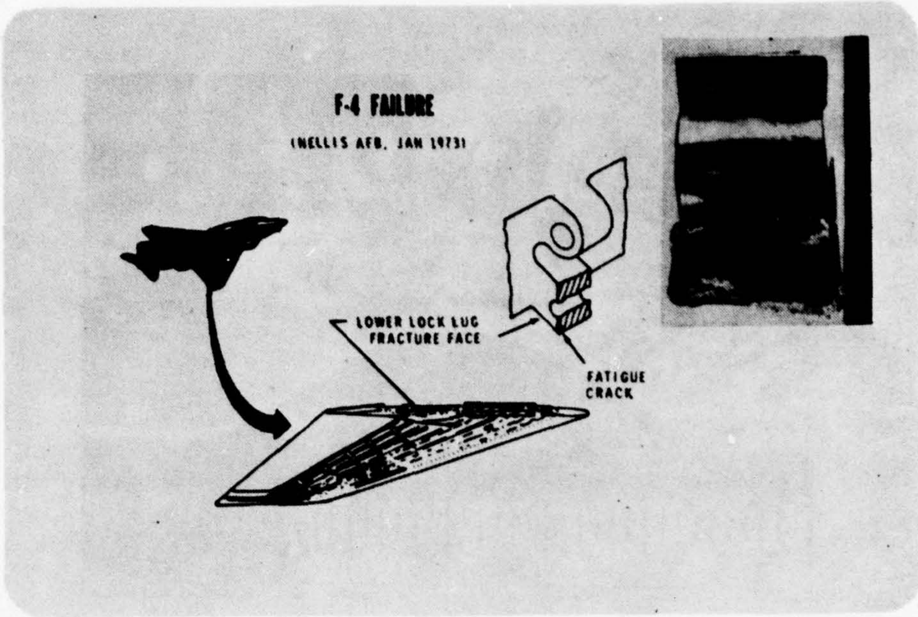

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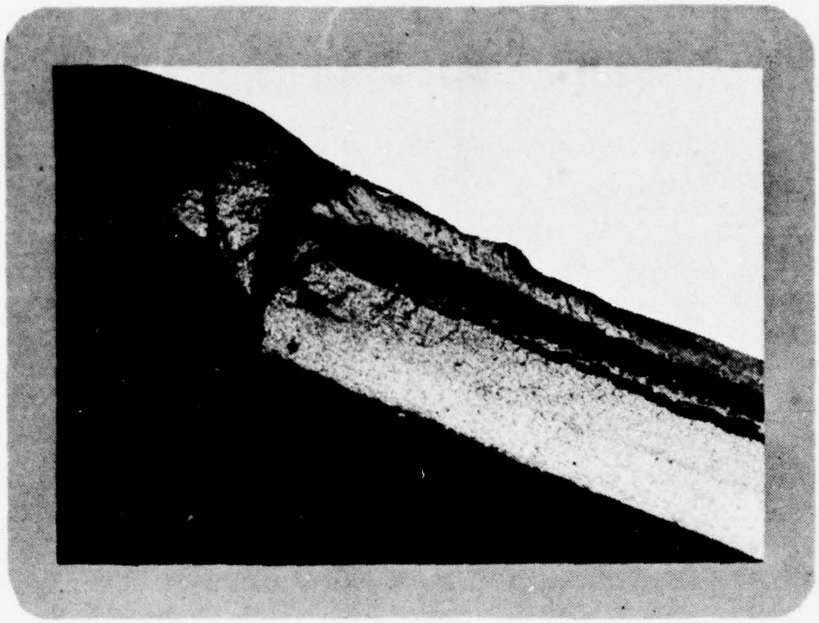
SLIDE B9



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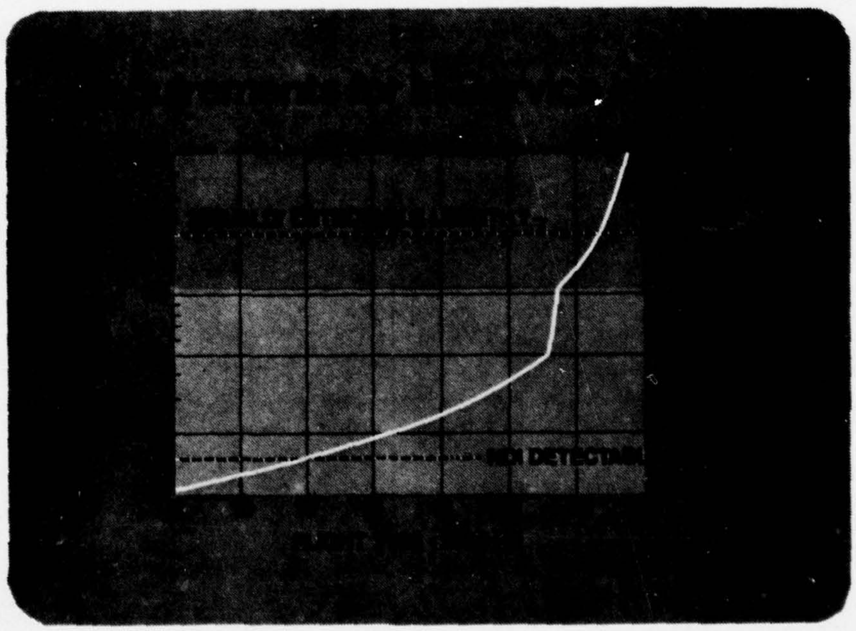

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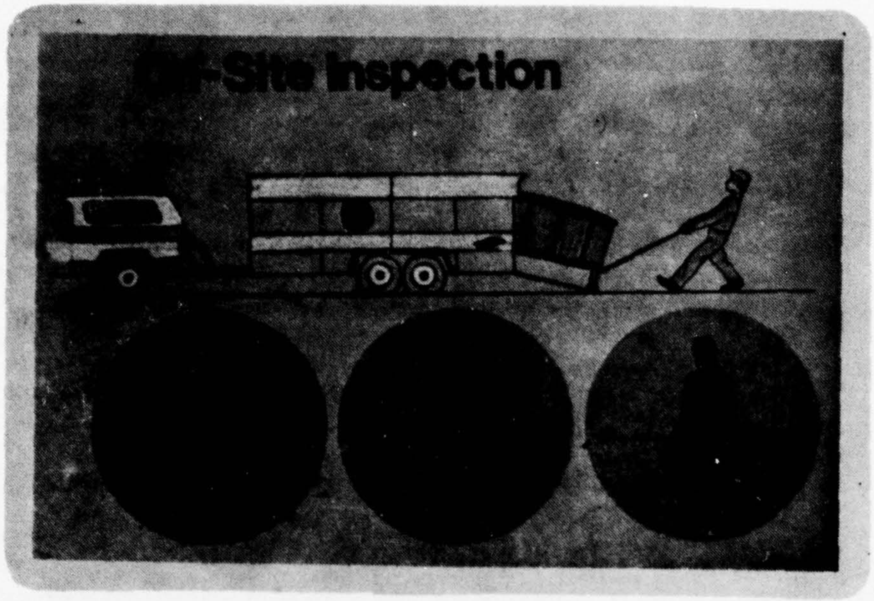

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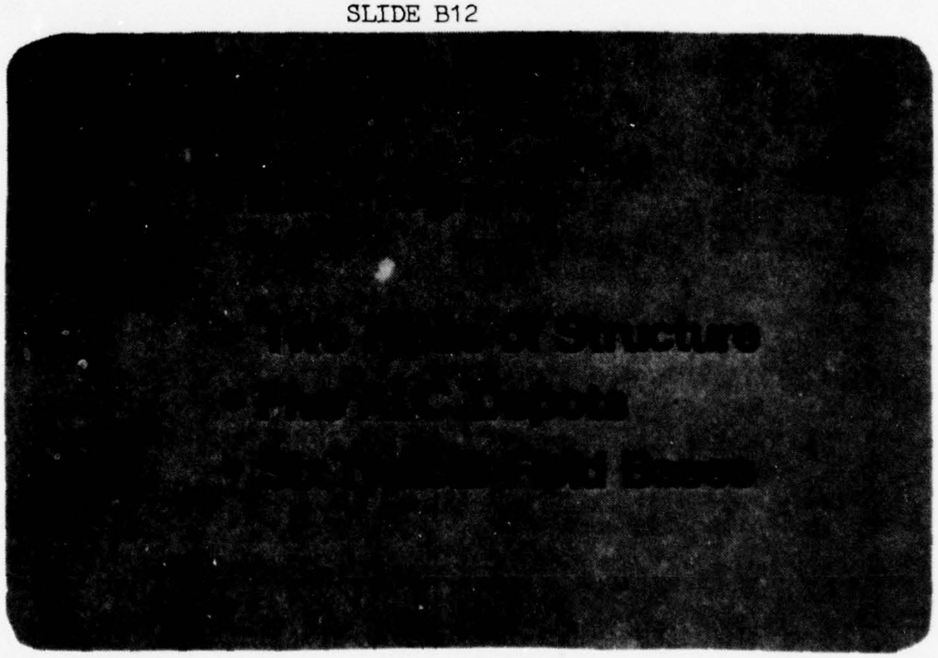

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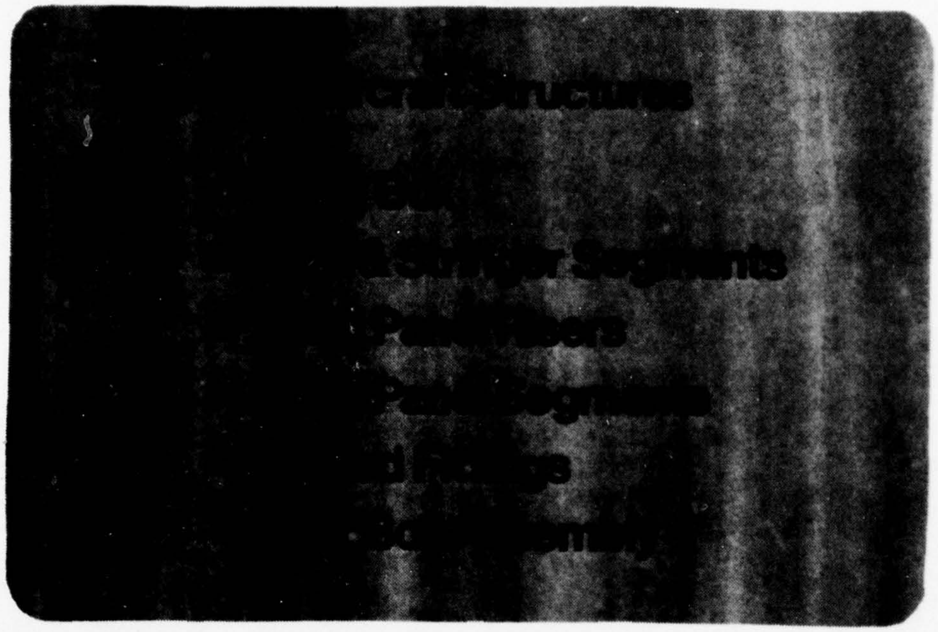

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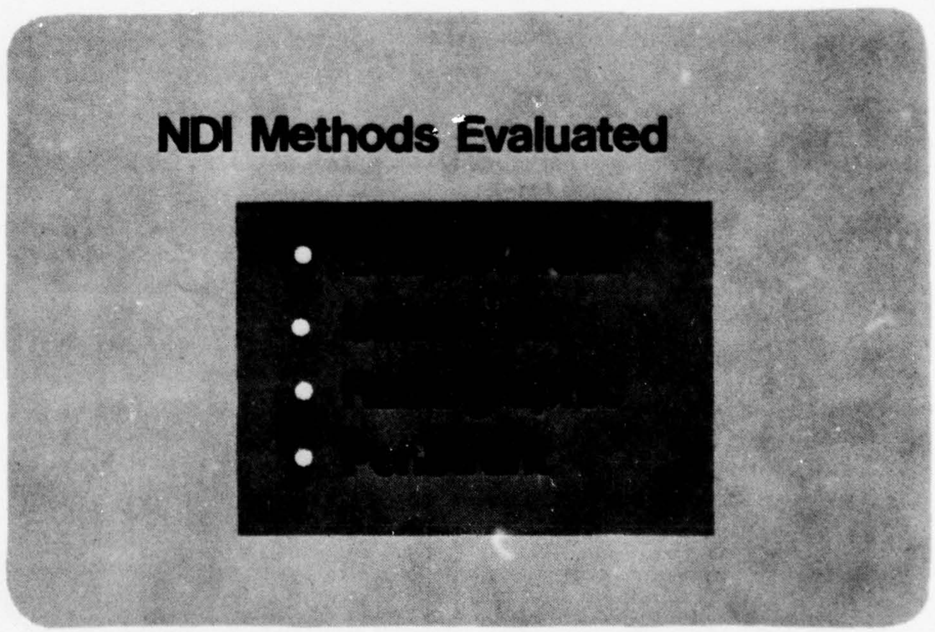

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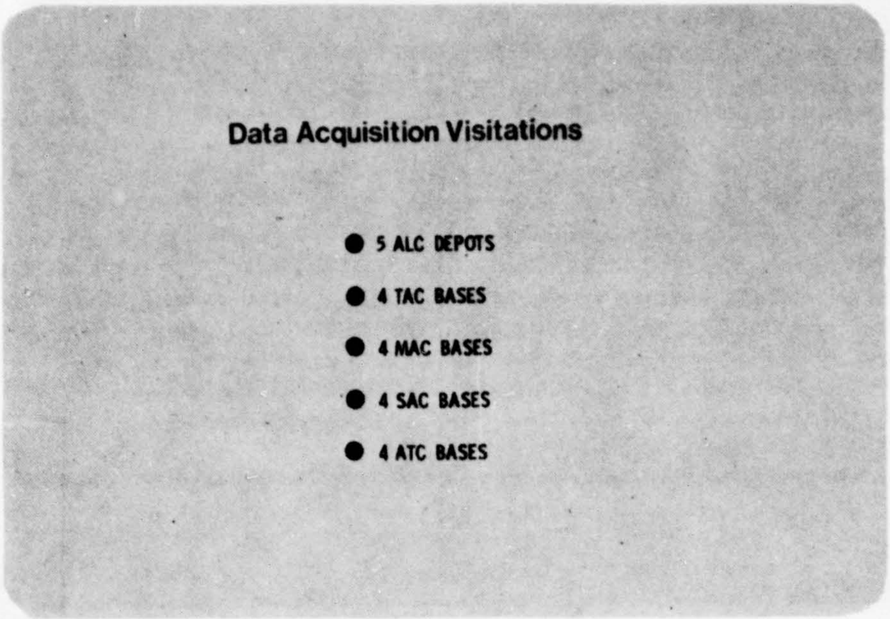

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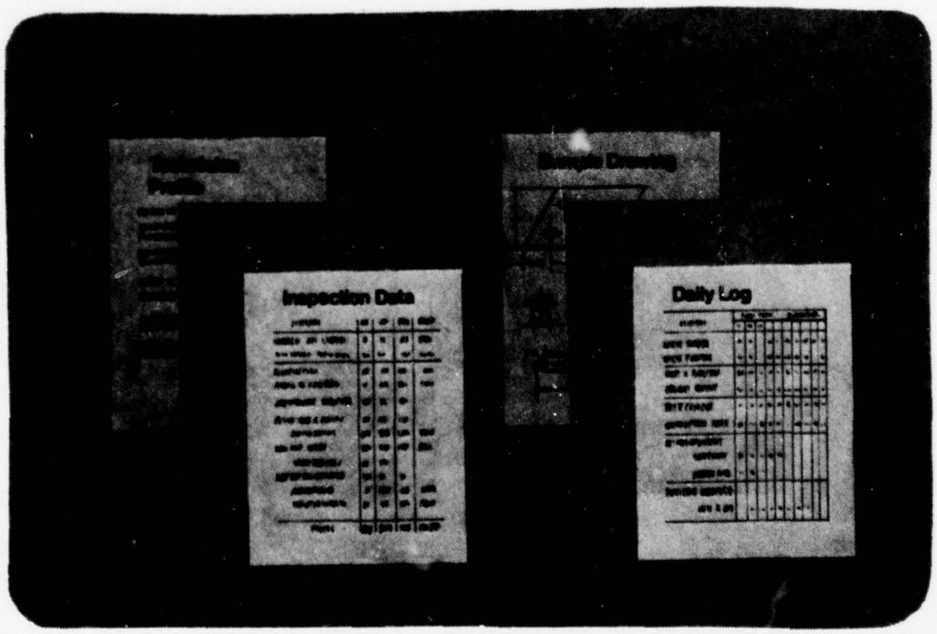

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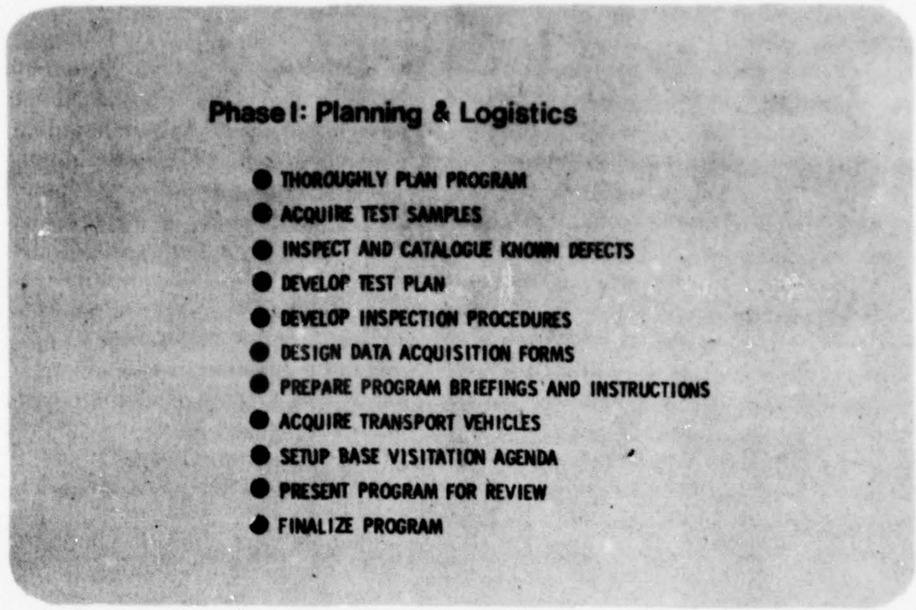

Phase I: Planning & Logistics
THOROUGHLY PLAN PROGRAM
ACQUIRE TEST SAMPLES
INSPECT AND CATALOGUE KNOWN DEFECTS
DEVELOP TEST PLAN
DEVELOP INSPECTION PROCEDURES
DESIGN DATA ACQUISITION FORMS
PREPARE PROGRAM BRIEFINGS AND INSTRUCTIONS
ACQUIRE TRANSPORT VEHICLES
SETUP BASE VISITATION AGENDA
PRESENT PROGRAM FOR REVIEW
FINALIZE PROGRAM

APPROACH TO DATA COLLECTION - SAMPLES

SLIDE C1

The actual aircraft structures with cataloged fatigue cracks will be shown in the following slides with the NDI in-progress on each. All inspections were aimed at detection of flaws radiating from fastener sites, plus several drain holes in the first two sample types in the series. There was approximately a ten-to-one ratio of flaws-to-inspection sites in these samples. Each crack was treated individually where damage progressed from both sides of a fastner hole; so a cataloged flaw record, for example, would have flaw 101A and 101B listed for each side of the fastener hole. The NDI task size in most cases was designed to occupy approximately 8 hours, but no time limits were placed on the individual.

SLIDE C2

SAMPLE AET, GELAC

This intact, painted segment of a C-130 center wing box was designated sample A. A 2-foot wide by 6-foot long chordwise strip containing 528 fasteners and 14 drain holes comprised the inspection sample. Here, the trials for the eddy current procedure validation is being made.

SLIDE C3

SAMPLE AET, AF

This procedure involves circumferential scans around the sites with the aid of a circle template. There were originally 40 individual flaws cataloged in this sample by a very close inspection at Lockheed-Georgia using the circle template.

SLIDE C4

SAMPLE AUT, GELAC

The same Sample A was inspected by ultrasonic shear wave scans with the optical aid of a straight-edge to perform spanwise scans to detect chordwise cracks.

SLIDE C5

SAMPLE AUT, AF

Most participants didn't elect to use the straightedge guide because it tended to inhibit essential scanning motions.

SLIDE C6

SAMPLE BET, GELAC

The composition of Sample B was virtually identical with Sample A except that it was made-up from 12 pieces of painted wing cover with stringers attached. These segments were approximately 18" square, with four of them removed from the perimeter of a wing access cutout area. Eddy current surface scans which were identical to those on Sample A were being validated here.

SLIDE C7

SAMPLE BET(OH), GELAC

This sample, composed of the 12 pieces in-total, contained 742 fastener sites with 51 cataloged flaws. Here, the overhead NDI position is being checked-out in a dry run. Both bench-top and overhead procedures were employed in the data acquisition phase to determine the effect of position on results.

SLIDE C8

SAMPLE BET(OH), AF

In some cases, a team conducted the overhead eddy current surface scans to facilitate ease of inspection. We will be showing the comparison of results of bench top versus overhead in the overall results, later.

SLIDE C9

SAMPLE BRT, GELAC

Radiographic NDI was performed on the B sample with the equipment trailer serving as a simulated fuselage. Exposures were made individually with the segments positioned on a series of racks inside the trailer. Double film cassette loads were made for most exposures to accommodate different thicknesses of material.

SLIDE C10

SAMPLE BRT, AF

Almost all radiography exposures were conducted by pairs of individuals, as is commonly done in-practice. Film reading was, however, performed by only one of the pair in most cases.

SLIDE C11

SAMPLE CUT, GELAC

Sample C was composed of 26 bare titanium segments nestted between stringers inside the intact box, Sample A. Ultrasonic shear wave scans were performed near both upper and lower edges on both faces of each. A total of 364 sites, configured as half-holes, were examined with 54 flaws in that total.

SLIDE C12

SAMPLE CUT, AF

The ultrasonic procedure provided for an optional transducer guide to assist in positioning. This guide, however, was not used in most cases because it inhibited scanning motion which the individual sought to use in the inspection.

SLIDE C13

SAMPLE CPT, AF

The penetrant NDI on the C Sample was conducted alternately with ultrasonic NDI with oily couplant, to present a cleaning problem similar to in-service conditions. Conditions within the wing box simulated wing riser inspection.

SLIDE C14

SAMPLE DUT GELAC

Sample D was composed of two painted KC-135 wing panel segments with fasteners removed. A total of 105 holes, of which 10 were alledgedly cracked, was inspected by ultrasonic shear wave scanning around the perimeter.

SLIDE C15

SAMPLE DET, GELAC

These same panel segments were inspected by eddy current bolt-hole scans.

SLIDE C16

SAMPLE DET, AF

The field task was commonly performed as a bench-top activity.

SLIDE C17

SAMPLE EET, GELAC

Sample E was composed of a number of F-104 forged wing fittings attached to dummy cover plates. All fastener holes were open and eddy current bolt-hole NDI was performed on a total of 140 holes. Of these, 27 were cataloged as being potentially flawed.

SLIDE C18

SAMPLE EET, AF

This NDI task was also commonly peformed as a bench-top inspection in the field.

SLIDE C19

SAMPLE FET, GELAC

This structure, Sample F, was a C-5 wing spar configuration containing a symmetric assembly of cap, web and stiffener elements. It was used in a fatigue test to evaluate a fastener design. A total of 257 open holes composed the inspection sites. Here, the eddy current bolt-hold scan procedure is being validated for detection of 53 potential flaws.

SLIDE C20

SAMPLE FET, AF

The inspection areas on this structure were vertically positioned on each side. The bolt-hole inspections were all performed from the exterior.

SLIDE C21

SAMPLE FUT, GELAC

Ultrasonic NDI on this structure required access to both the interior and exterior, with scans performed using a shear wave technique.

SLIDE C22

SAMPLE FUT, AF

Ultrasonic shear wave scans on the exterior were made to detect cracks in the 0.060" thick web, under the vertical stiffeners, while those on the interior were conducted on the 0.25" thick extruded cap. This structure presented the most difficult challenge, for NDI among all structure samples used in the program.

SLIDE C23

SAMPLE GET, AF

A new sample type was introduced at the 18th base, for use throughout the remainder of the data acquisition effort. A total of 76 specimens 1/4" thick, 2" wide by 16" long, containing ten countersunk fastener holes, 3/16" diameter, were designated as Sample G. These specimens contained a total of 1520 machine grown fatigue cracks at randomly located holes. Inspections were conducted by ultrasonic shear wave and eddy-current bolt hole scans to detect the flaws.

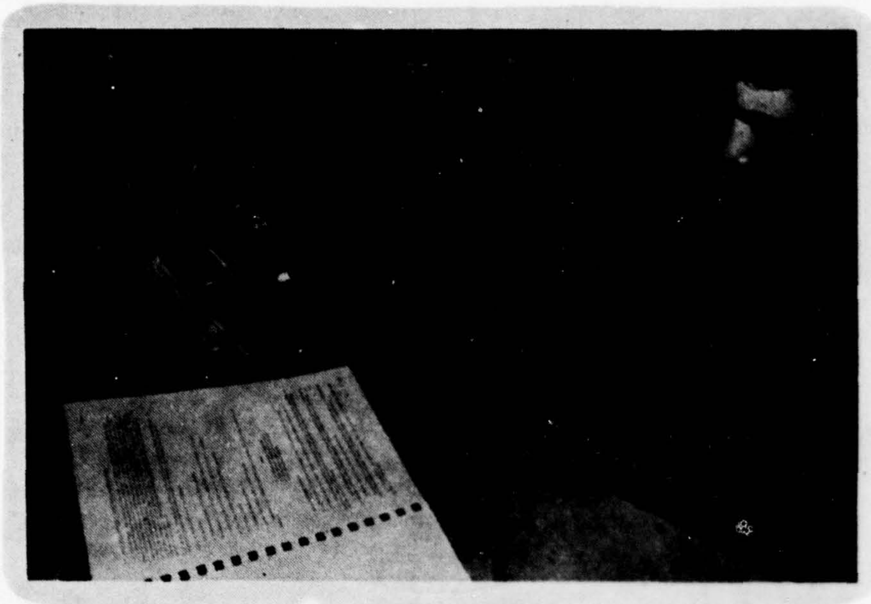
The purpose of this was to determine for the Air Force Materials Laboratory what relationship exists between NDI performance on simple flat plates with machine grown flaws and assembled structure with service induced flaws. Joe Moyzis will be discussing this activity in more detail this afternoon.

And now, the discussion of the data collection will be provided by Bruce Dodd.

SLIDE C1

SLIDE C2

SLIDE C3



SLIDE C4

SLIDE C5

SLIDE C6

SLIDE C7

SLIDE C8

SLIDE C9

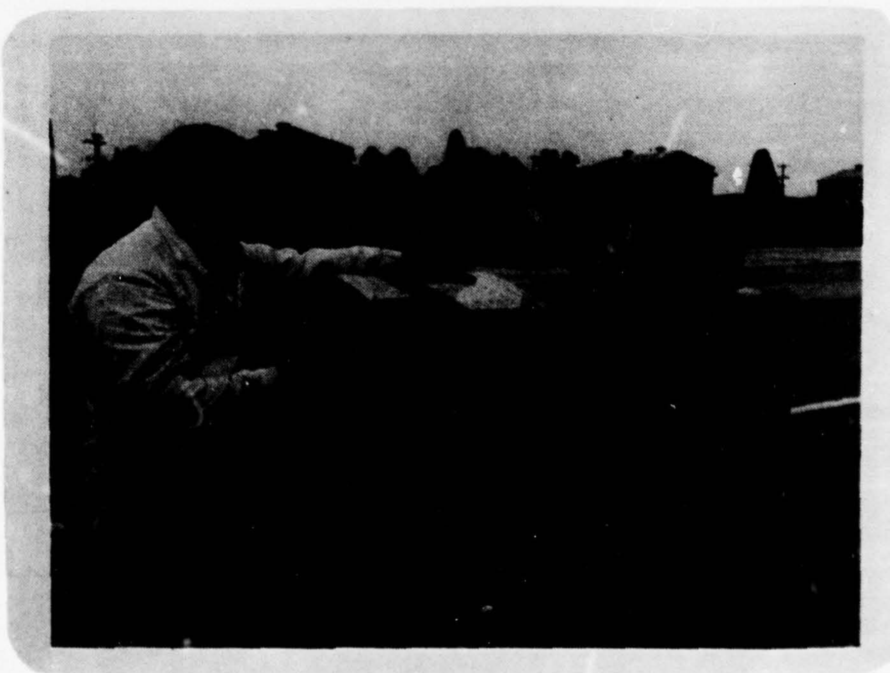
SLIDE C10

SLIDE C11

SLIDE C12

SLIDE C13

SLIDE C14



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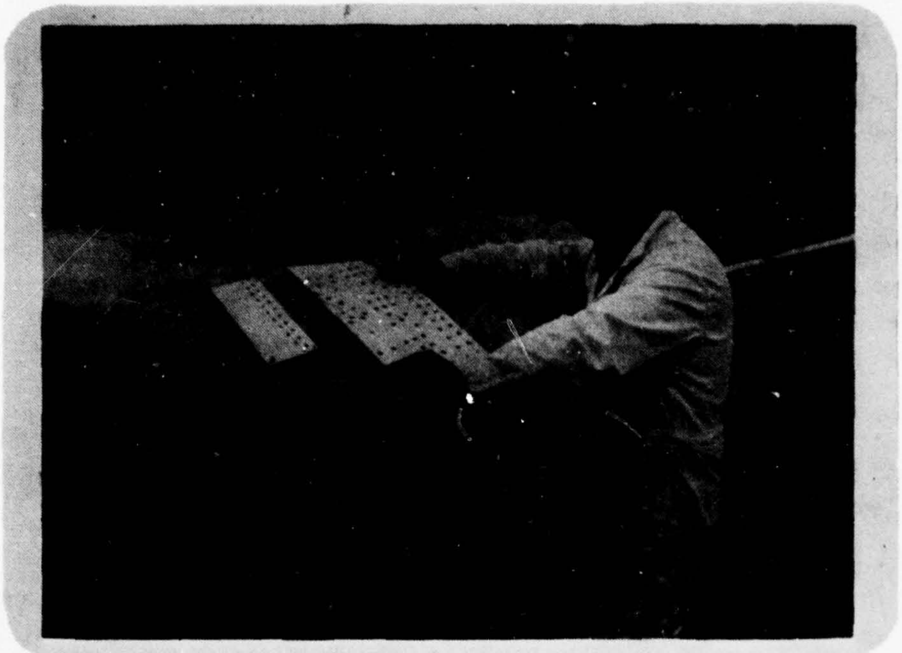

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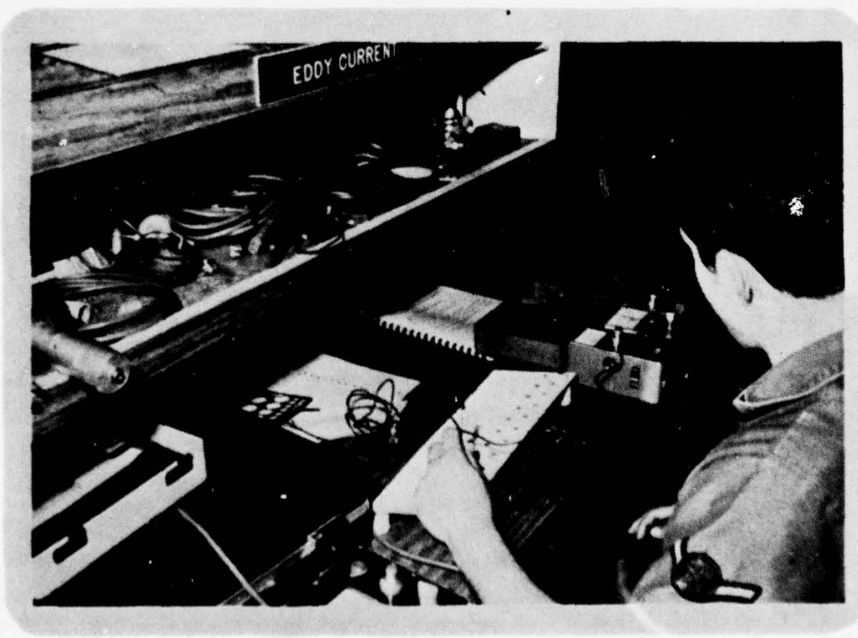

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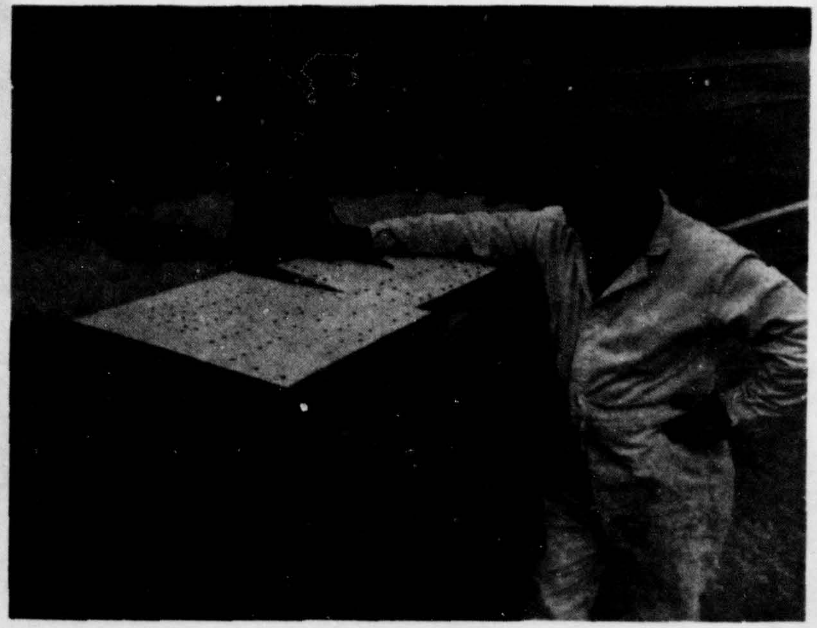

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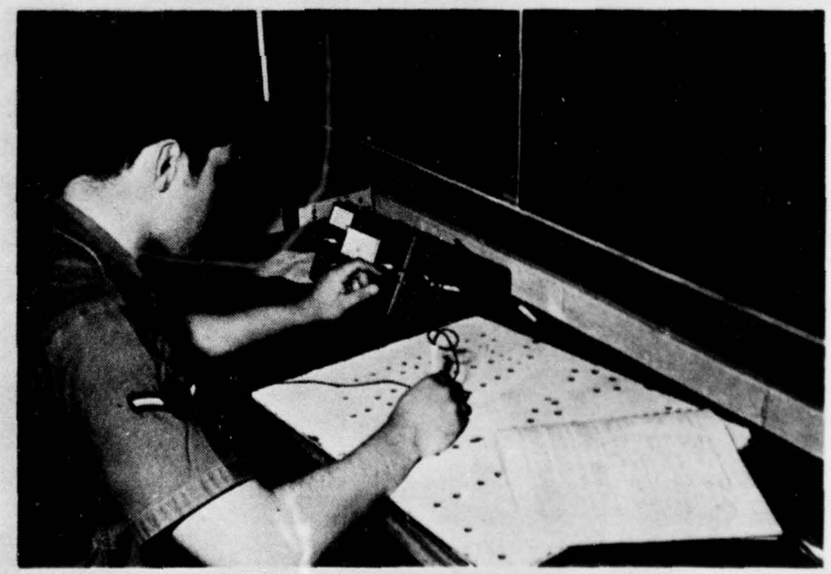
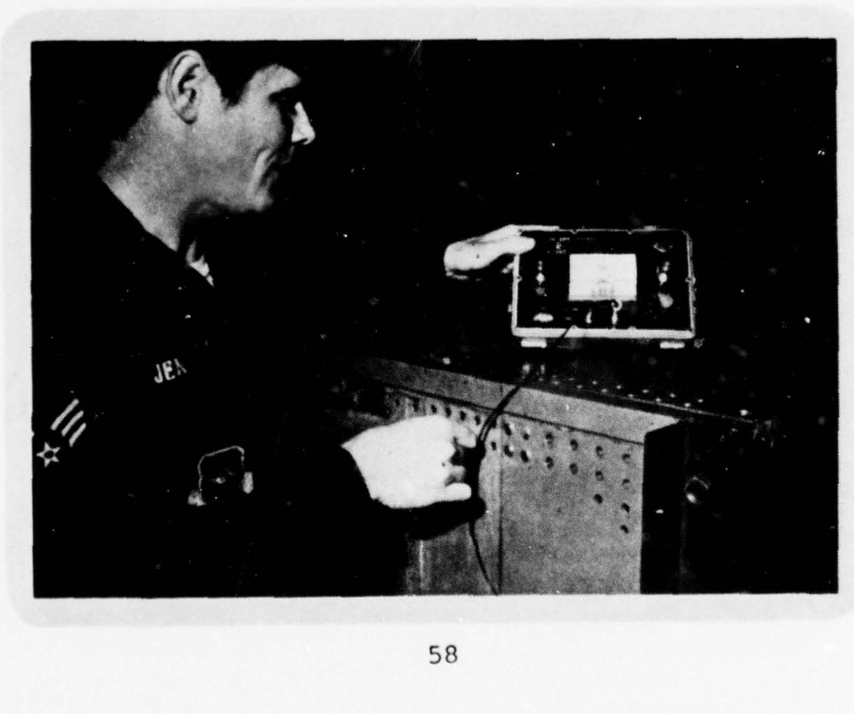


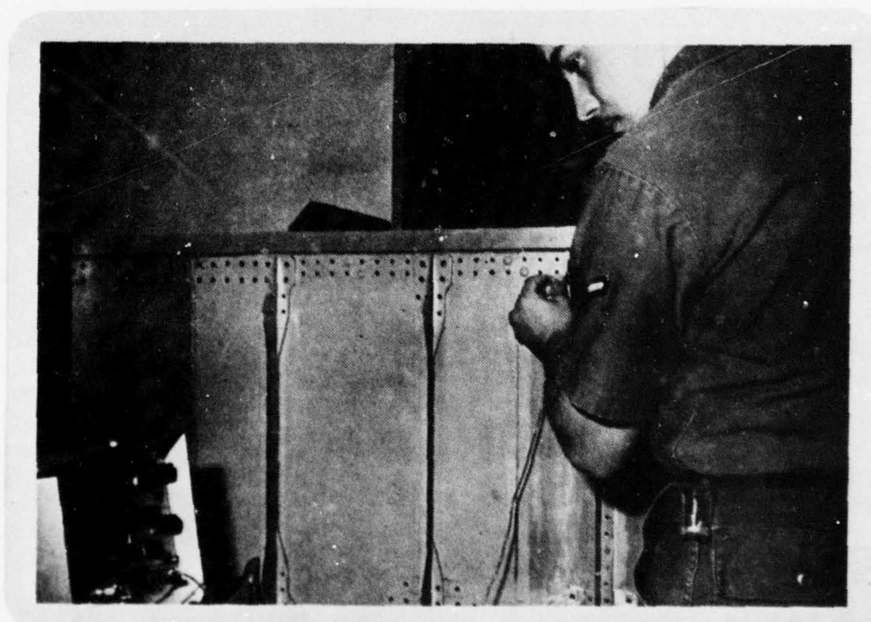
SLIDE C19

SLIDE C20

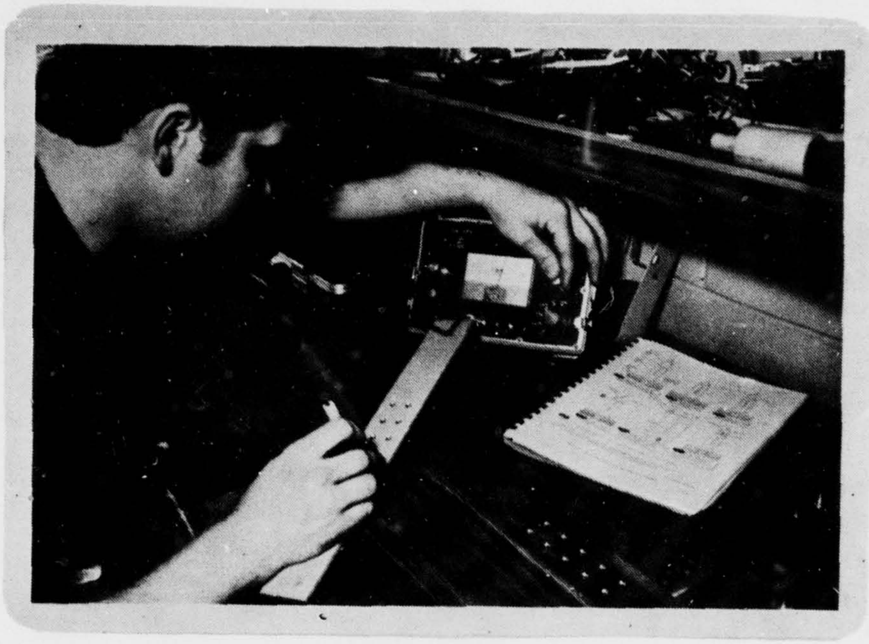


SLIDE C21

SLIDE C22



SLIDE C-23



APPROACH TO DATA COLLECTION - DATA COLLECTION

SLIDE D1

The data collection phase of the program was very carefully planned and implemented. Our objective was to present an identical task to each of a number of separate NDI organizations and passively measure technician performance under their home base conditions. We wished only to control the samples and the NDI techniques which were to be used to inspect them. Since we were trying to measure performance under locally accustomed conditions, we did not wish to influence individual proficiency nor attempt to control the ambient variables in any way. The program required that we use NDI technicians normally assigned to such tasks at each base and that they perform under procedures and conditions that are routine for the base. Ideally, since the tasks were always the same, one might expect each technician to accommodate to the conditions he was oriented to and perform to the best of his ability, leaving proficiency as the only real variable. However, experience had shown us that proficiency is not always independent of a host of ancillary variables. The individual technicians's reactions to these variables constitute what we may refer to as "human factors," and these human factors may tend to broaden the measured variations in performance.

SLIDE D2

During the data collection phase, we visited 21 separate Air Force installations. All five Air Logistics Command bases were selected for evaluation; then, four bases were selected by the Air Force Command Monitors from each of the ATC, MAC, SAC and TAC commands. Care was taken to construct a representative cross-section of the command with the bases selected. A total of 298 NDI technicians participated in the program and ranged from three technicians at two bases to as many as 47 technicians at one ALC depot. Considering this number of technicians and the variety of bases, we could reasonable expect the uncontrolled variables to change over a wide range of possibilities. The controlled variables, on the other hand, which included the

samples, the NDI standards and the NDI procedures, were constant from base-to-base and, therefore, provided the uniform base line required for direct comparison of performance.

SLIDE D3

I believe the best way to illustrate to you how the data collection functions were conducted is to take you through the typical sequence of activities from arrival at an Air Force facility to departure. I was the Lockheed engineer in the field for this program and was responsible for its day-to-day conduct. All program equipment and the structure samples were transported from base to base in a 16-foot utility trailer which was pulled by a one ton pick-up truck.

Upon arriving at an installation the first concern was to acquaint the NDI personnel with the purposes and conduct of the program. We did this by giving program briefings to management personnel and to the NDI technicians. Both these briefings were delivered by means of a desk top slide projector that contained its own screen and a cassette tape player to make the oral presentation. This approach provided identical briefings at all bases, thus avoiding a potential bias in attitude and understanding. The management briefing described the program and its goals and included a discussion of how program results will interact with associated engineering technologies. The technician briefing described the program and informed the technicians what they were to do in the program and how to complete the data sheets. Each of these cassette briefings are available here and are set up in the back of the room. If any of you are interested in seeing these, I will be happy to play them during our break.

SLIDE D4

The next major task was to set-up the samples and equipment in preparation for inspection. The actual set-up location and arrangement varied somewhat from command to command, with minor variations at the bases within each command. Typically, the unloaded trailer would be parked in the x-ray lab, or outside the x-ray shop or inside a hangar. The x-ray and the overhead

eddy current NDI tasks were conducted using the trailer for a sample mount. The structure samples and auxiliary equipment were usually set up in the inspection shop or in a nearby unused space where the lighting and temperature could be kept within comfortable limits. We attempted to make the location and ambient conditions as similar as practical to the conditions the technician was routinely accustomed to. The program principal engineer, Bill Sproat, was present with me at each base during the briefings and set-up period.

SLIDE D5

The next step would be giving assignments to the NDI technicians who had been selected to participate. Once the assignments were made, each technician was given a copy of the program NDI manual and he familiarized himself with the particular procedure he would use in his assignment. After completing his assignment, the technician would normally be assigned another inspection task as long as he continued to be available.

SLIDE D6

Thorough data collection was truly the heart and purpose of the program. To collect the data necessary to perform an adequate evaluation, we designed the six types of data collection forms indicated on this slide. Three of these were to be filled out by the technician and the other three filled out by the Lockheed field engineer. These forms provided for recording of personal data from each technician, equipment parameter values, flaw indications found in the samples, and information about the local facilities available. A daily log was kept to record environmental data and day-by-day program activity. I will now describe each of these forms in more detail so that you will be more aware of the data that is now available.

SLIDE D7

TECHNICIAN PROFILE FORM

The technician profile form was completed by each participating technician at the beginning of the program at his facility. The purpose was to gather background

information on all technicians participating in the program. Since individuals were not evaluated by name, their names were not recorded; however, numbers were assigned so that we could coordinate other completed data forms with a specific unidentified technician. On the technician profile form, the technician recorded his assigned ID Number, Job Title or AFSC, general educational information, specific information about his NDI training and experience, job history in and outside the Air Force and specific physical data such as age, weight, height, sex, marital status and physical limitations. We wanted this data in order to determine if certain types of backgrounds, formal training, job experience, physical types, and so on, have any relationship to NDE performance. Such factors, if shown to have valid effects on NDI reliability, could be used to establish the basis for an effective selection or screening program for future NDI personnel.

SLIDE D8

EQUIPMENT PERFORMANCE

Specific performance checks were made on the ultrasonic, eddy current, and x-ray equipment and the penetrant materials that were used at each base. Equipment performance data sheets were filled out by the Lockheed engineer to record the results of specified checks on the NDI equipment and materials. The data sheets provided spaces for completely identifying the equipment and materials, equipment settings, test set-up parameters, process information and response or performance data. These checks and resulting information allowed us to evaluate to some degree the condition of the equipment at each base. Generally, we found that if the equipment was in service it was working satisfactorily. Malfunctioning equipment was either out of service or in the repair shop.

SLIDE D9

NONDESTRUCTIVE INSPECTION DATA

Inspection data sheets were provided for each technician to record specified information before and

during each inspection. There was a separate data sheet for each technique, but similar types of information were requested pertaining to equipment identification, equipment settings, standards, transducers, probes, materials, inspection start and stop times and technician comments. Note that this form did not request information about defects found in the sample. The technician was instructed to mark indicated defects directly on the structure sample and to transfer these marks to a sample data sheet following the inspection of that sample. Defect markings were made on the sample using an erasable marking instrument, and were completely removed before the sample was assigned to the next technician.

SLIDE D10

SAMPLE DATA SHEETS

These sheets were actually outline drawings of the sample to be inspected, and included all fastener holes to be inspected. These sheets were used to transfer the defect markings from the sample to the corresponding location on the drawing at the completion of the inspection. Before removing the marks from the sample, the Lockheed engineer visually compared markings on the sheet to those on the sample to verify correctness and to be sure that he understood the technician's markings. The technician was instructed to mark it on both sides of the hole if there were cracks on both sides.

SLIDE D11

FACILITY EVALUATION FORM

The facility evaluation form was used to record information about the set-up location, ambient conditions, light and noise levels, ancillary equipment, and a description of the inspection area.

DAILY LOG

The Lockheed engineer also maintained daily records pertaining to progress on the program, weather conditions, special conditions, instrumentation

operations or problems, and pertinent comments about the technicians participating.

This now provides you with an overview of the types of data we collected. Now, I will briefly summarize the scope and level of participation we experienced throughout the data collection phase.

SLIDE D12

PARTICIPATION LEVEL

A summary of the participation levels at the various commands is given in this slide. We are showing the command, number of technicians that participated and the number of tasks that they completed. Now a task is defined as: one NDI technique performed on one structure sample type. Complete and partial tasks were both counted. We had a total of 298 participating technicians who performed 777 total tasks. I might add, these technicians inspected a total of over a half million potential flaw sites. On the average, then, each technician inspected over 1800 sites. Note that the number of participating technicians and the number of tasks completed are about evenly divided between the depots (AFLC's) and the field bases.

SLIDE D13

NDI TECHNIQUE USAGE

To give you an idea of the level of usage each of the NDI techniques received during the program, this slide shows the number of tasks completed for each technique. We didn't include the screening sample tasks (the 'G' samples) in this summary. The automated ultrasonic equipment which will be described later today, was used at three bases and was applied to only one type of structure sample - thus accounting for its low usage. By contrast, the automated eddy current bolt hole scanner which will also be described in a later presentation was used at six bases and was applied to three structure sample types. The more routine ultrasonic and eddy current techniques received substantial usage at

most all of the bases. The penetrant and x-ray procedures were applied to only one structure sample type each and were used at 16 and 14 bases, respectively. Because of manpower availability, not all structure samples and NDI technique combinations were evaluated at all bases.

SLIDE D14

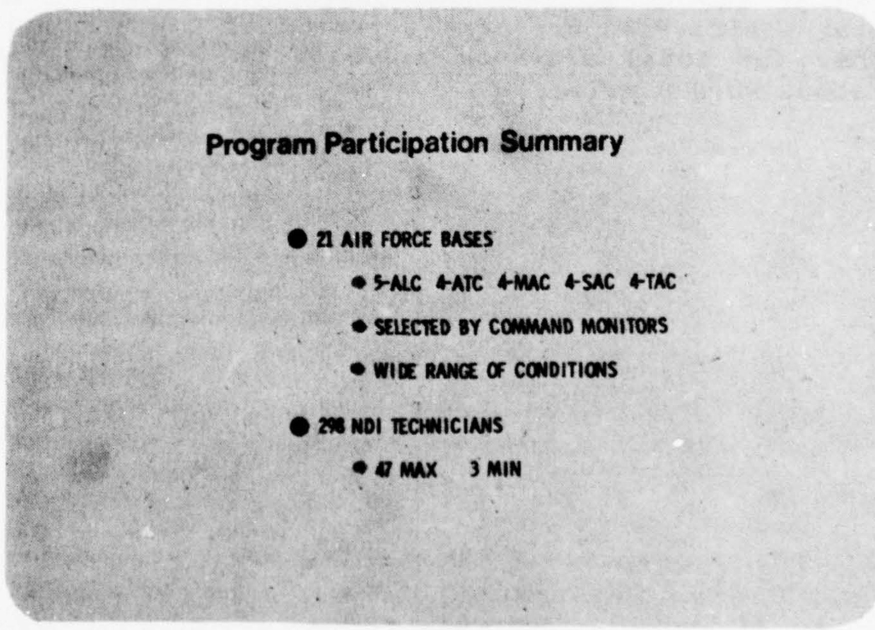
This matrix shows how the tasks were concentrated with respect to the structure sample type and the NDI technique. The chart indicates how the plan dedicated specific NDI techniques for inspection of each structure type. The cross-hatched blocks are deliberate omissions in the matrix.

SLIDE D15

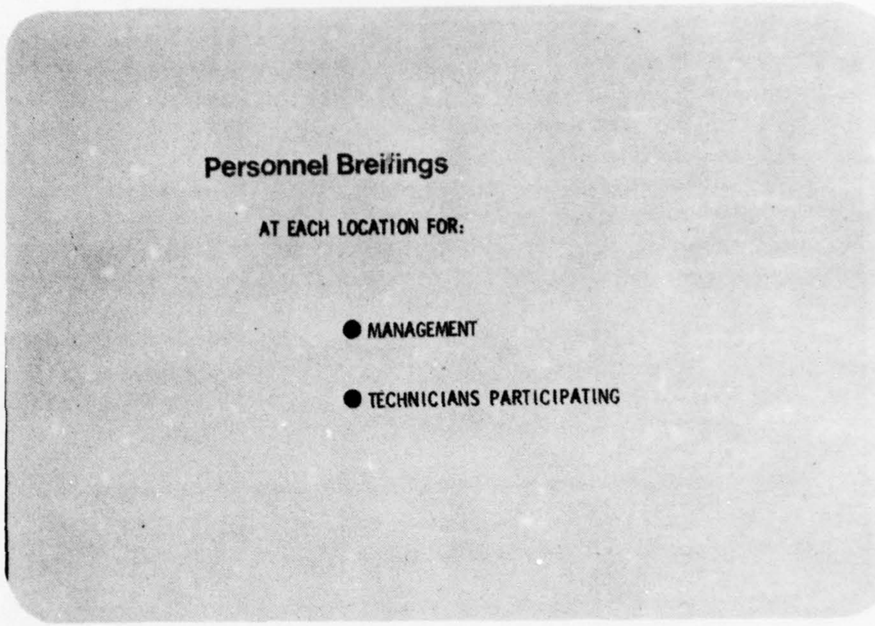
This final slide shows how the 21 Air Force bases who participated in the program were distributed throughout the country. The color coding indicates the type of command to which a particular base belongs. Wright-Patterson AFB, although not a participant in the data collection activities, was the first base to be visited so that we could conduct a dry run of the program. As you see, the bases were located in every geographic region of the U. S. The data collection phase of the program was carried out over a period of 2 years and 3 months. The total distance traveled during that time was about 50,000 miles.

SLIDE D1

SLIDE D2



SLIDE D3



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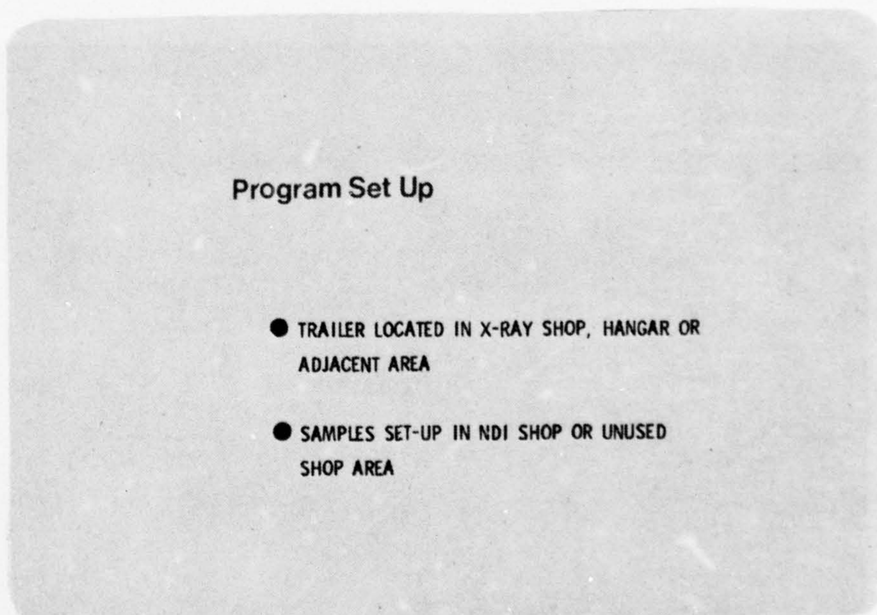

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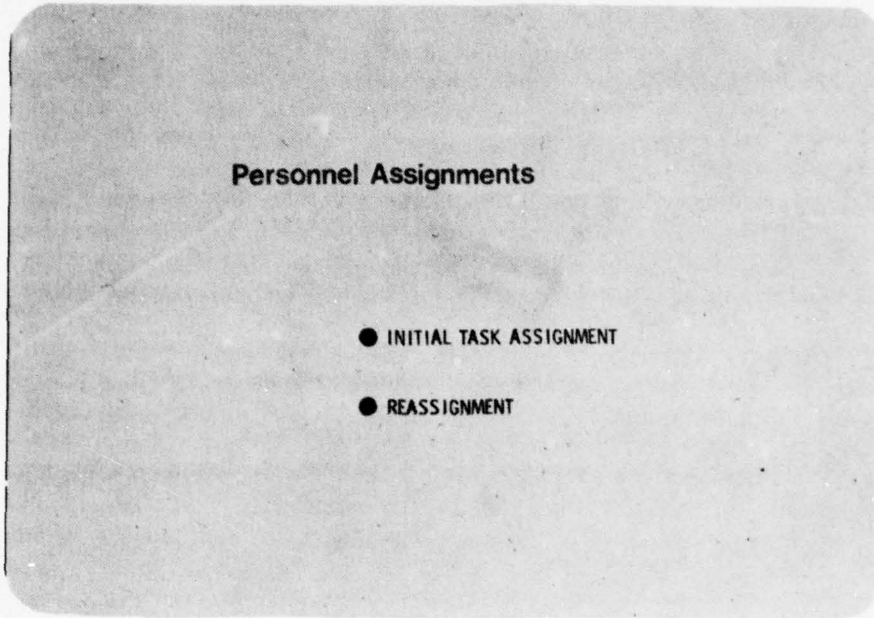
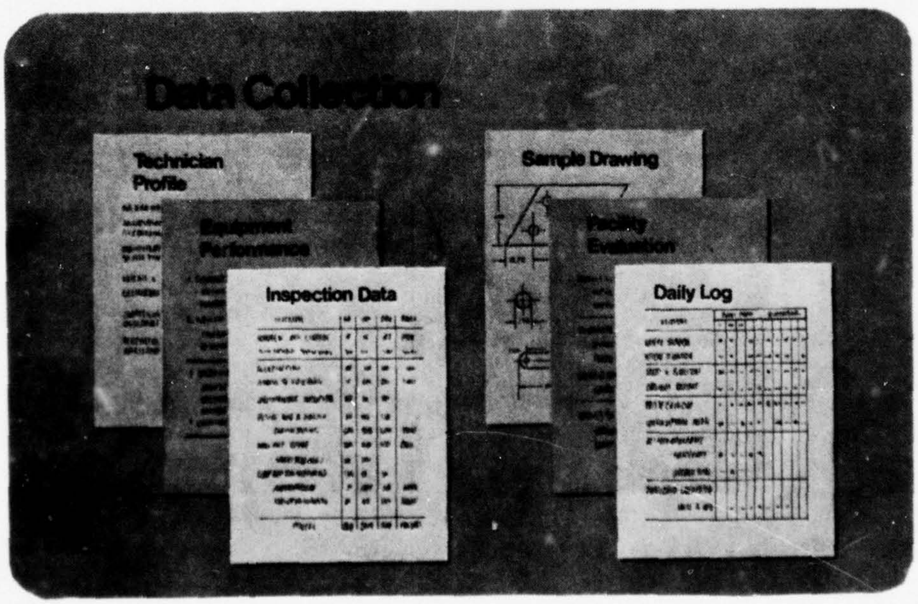
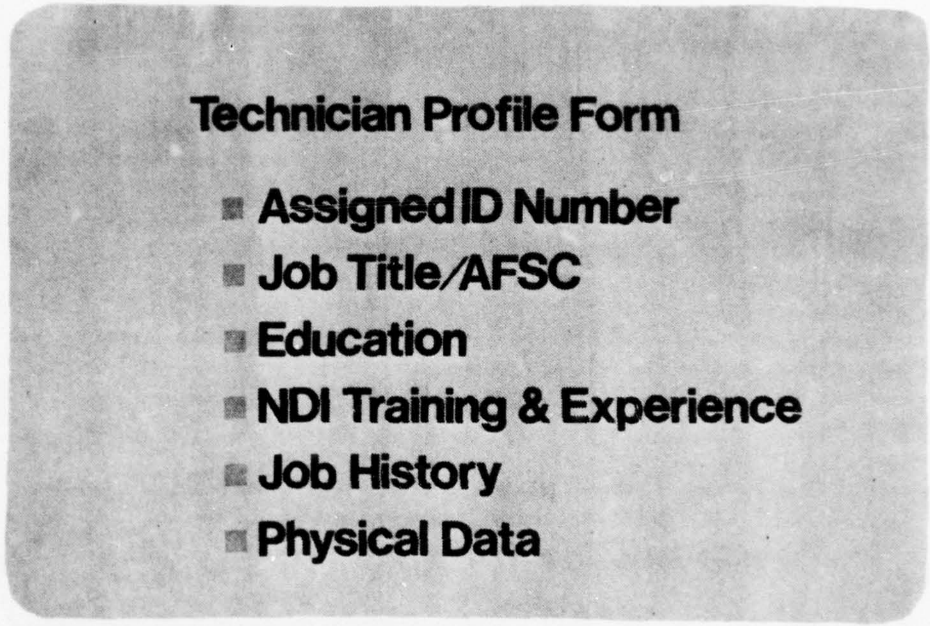


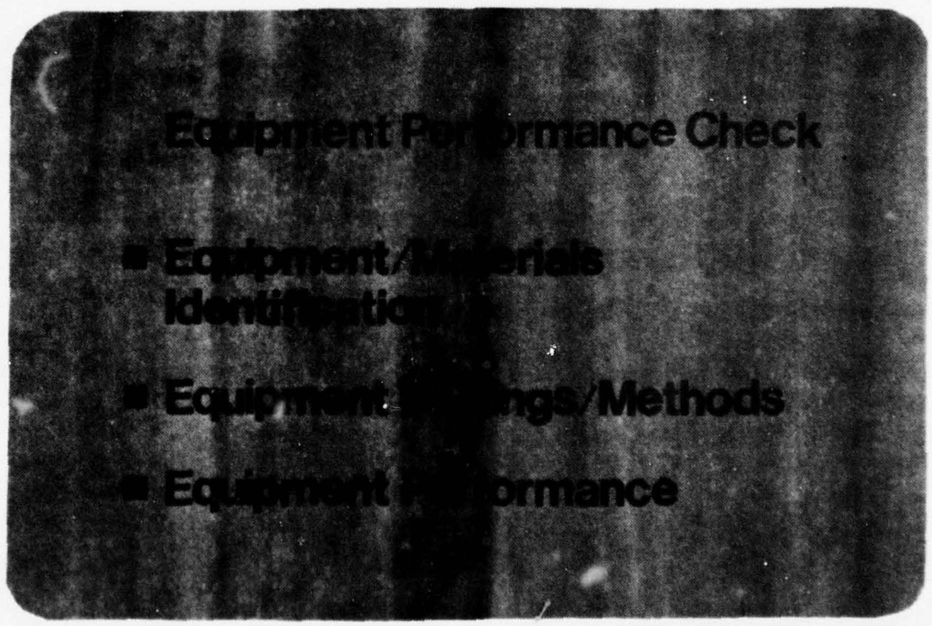
SLIDE D6



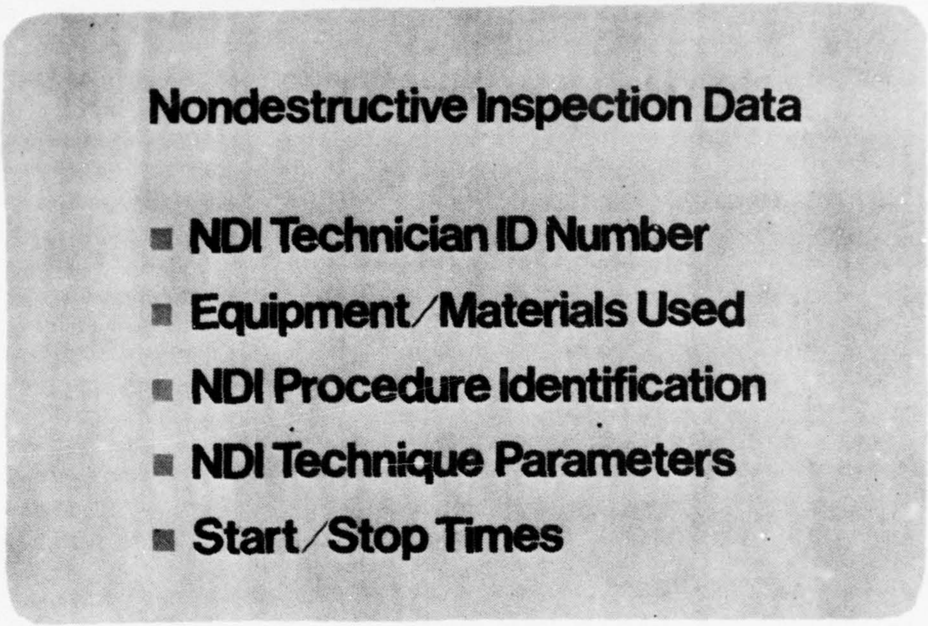
SLIDE D7



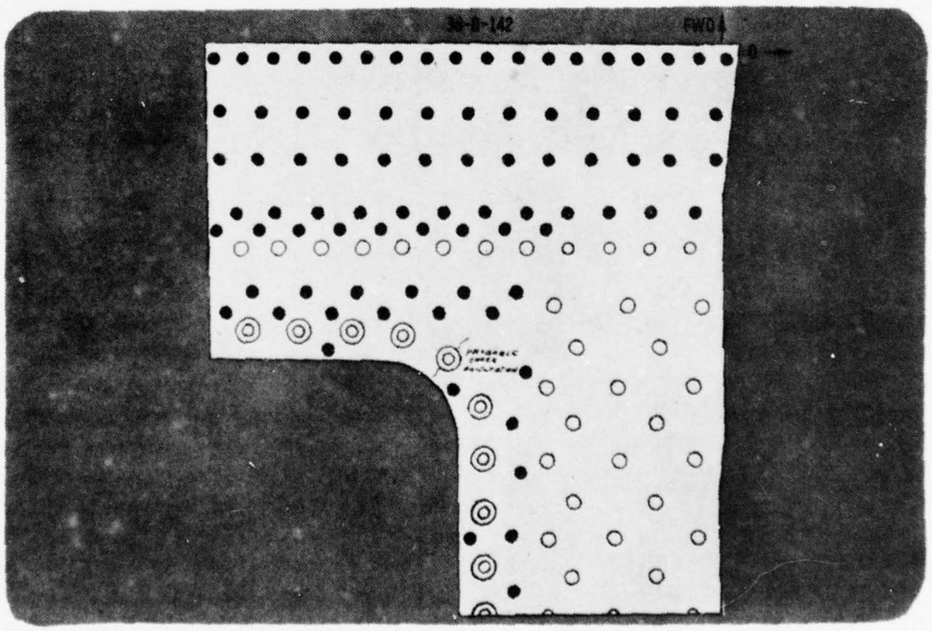
SLIDE D8



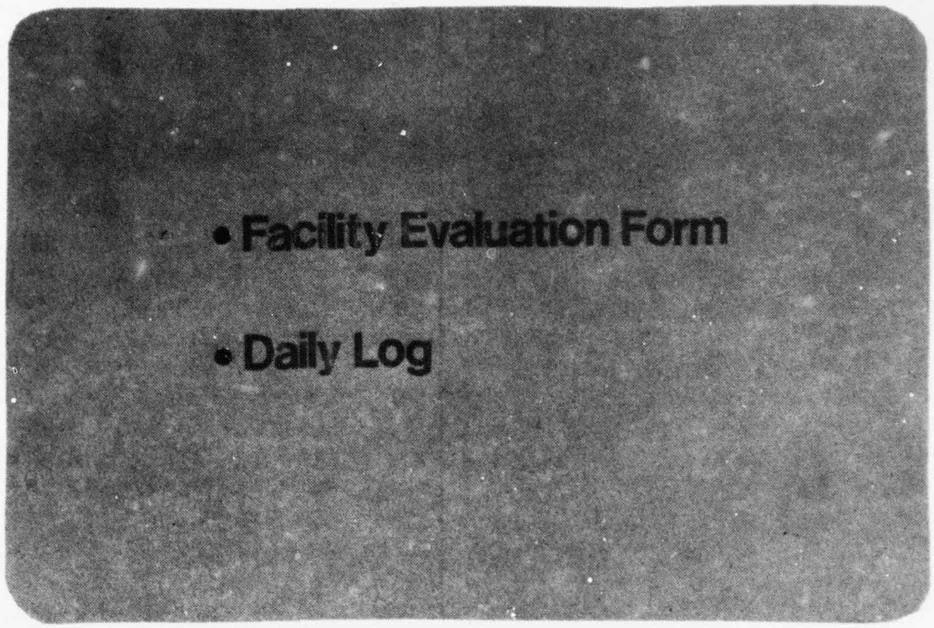
SLIDE D9



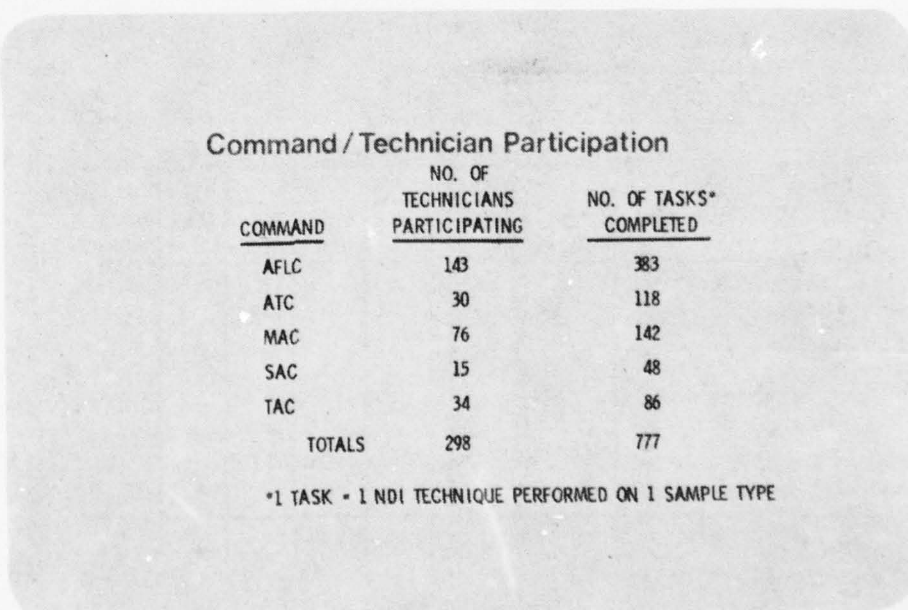
SLIDE D10



SLIDE D11



SLIDE D12



Command / Technician Participation

COMMAND	NO. OF TECHNICIANS PARTICIPATING	NO. OF TASKS* COMPLETED
AFLC	143	383
ATC	30	118
MAC	76	142
SAC	15	48
TAC	34	86
TOTALS	298	777

*1 TASK = 1 NDI TECHNIQUE PERFORMED ON 1 SAMPLE TYPE

SLIDE D13

Tasks Completed per NDI Method

NDI METHOD	TASKS●
ULTRASONIC, MANUAL	160 1/2●
ULTRASONIC, AUTOMATED	4
EDDY CURRENT, SURFACE SCAN	165 1/2●
EDDY CURRENT, BOLT HOLE, MANUAL	253 3/4
EDDY CURRENT, BOLT HOLE, AUTOMATED	44
PENETRANT	63
RADIOGRAPHIC (X-RAY)	61
TOTAL	751 3/4

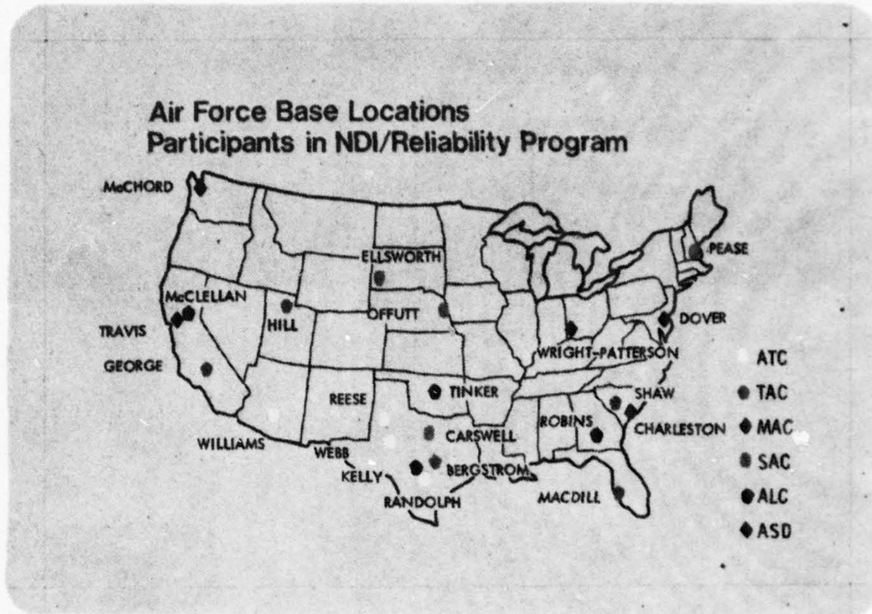
●EXCLUDING SCREENING SAMPLE INSPECTIONS

SLIDE D14

Field & Depot Tasks per Sample & NDI Technique

STRUCTURE SAMPLE	TASKS COMPLETED PER NDI TECHNIQUE						
	ULTRASONIC		EDDY CURRENT				
	MANUAL	AUTO-MATIC	SURFACE SCAN	B.H. - MAN	B.H. - AUTO	PENE-TRANT	RADIO-GRAPHIC
A - C-130 WING BOX	53	4	63 1/2				
B - C-130 WING BOX SEGMENTS			102				61
C - WING RISERS	32					63	
D - KC-135 WING SECTIONS	46 1/2			71 1/2	9		
E - F-104 WING FITTINGS				105 1/2	21 1/2		
F - C-5 BOX BEAM	29			76 3/4	13 1/2		
G - SCREENING FLAT PLATES	9 1/4		16				
TOTALS	169 3/4	4	181 1/2	253 3/4	44	63	61

SLIDE D15


Air Force Base Locations
Participants in NDI/Reliability Program
McCHORD
ELLSWORTH
PEASE
McCLELLAN
HILL
OFFUTT
DOVER
TRAVIS
WRIGHT-PATTERSON
GEORGE
TINKER
SHAW
REESE
CARSWELL
ROBINS
CHARLESTON
WILLIAMS
WEBB
KELLY
BERGSTROM
RANDOLPH
MACDILL
ATC
TAC
MAC
SAC
ALC
ASD

SLIDE E1

TEARDOWN RESULTS

So far, we have seen what the structures looked like and how the data acquisition progressed. Now, the discussion will center around the measurements of the flaws by destructive methods.

Following the completion of the Phase II, Data Collection, a teardown examination was made of the program samples to accurately determine and fully characterize their defect content. In the planning phase, we initially catalogued all known defects and estimated their uncovered lengths using careful visual and eddy current examination. In order to provide an accurate evaluation of Air Force NDI capability based on data collection from these samples, it was necessary to acquire complete and accurate information about the flaw sites.

In addition to the initial information, the teardown inspection provided (1) knowledge of additional flaws, unknown in the planning phase, for a complete accounting of all cracks, (2) confirmation of the existence of flaws at locations which exhibited a high incidence of "false calls," and elimination as suspect, those sites which exhibited NDI indications but contained no actual flaw, and (3) a direct accurate measurement of the geometry and orientation of identified flaws.

SLIDE E2

SCOPE

All structure samples, except for type C and G structure samples, were included in the teardown inspection. Since the characteristics of service-induced flaws vary widely, the complete parameters cannot be defined from surface length measurements alone. Since the actual structure samples contained natural flaws, it was therefore necessary to subject them to the teardown inspection. The type C and G samples, on the other hand, contained flaws which were machine induced under closely controlled conditions. The size and shape of those flaws were therefore known with sufficient detail for analysis without further examination.

SLIDE E3

INITIAL PREPARATION

The teardown examination can be separated into two activities, which were the initial preparation and examinations and the destructive examinations. The initial stage included the sequence detailed on this chart. In general, the sequence included disassembly of the sample, stripping of surface finish, several steps of cleaning and etching, visual and penetrant inspections to determine all suspect flaw sites, marker identification of each suspect area, sectioning layout on the part, photographing the part, sectioning them into individual laboratory specimens containing the suspect flaw, and additional cleaning with a mild alkaline solution followed by an ultrasonic cleaning.

Structure samples A, B, E and F were totally disassembled. The sample A portion was cut from the intact wing box, rivets sheared off at the buck tail and skins removed from stringers. Sample B was treated in the same manner but no initial cutting was required. Sample D required no disassembly and sample E breakdown was achieved by unbolting the cracked fittings from the dummy cover plates. Sample F sections were cut from the total box beam and separated into spar caps, webs and web stiffeners. Paint was removed from all structure samples with a paint stripper. After stripping, the samples were cleaned in an alkaline solution, water rinsed, dipped in an acid neutralizing bath, water flushed and oven dried.

Fluorescent penetrant inspections were performed on the samples by QA laboratory personnel. Flaw indications were identified on the pieces at all suspect locations using a red marker. Samples A and B were also inspected further with a special automatic eddy current surface scanning device, developed at Sacramento ALC. The results of the penetrant and special eddy current scans, along with high incidence of "false calls" derived from the field data, were added to the list of flaw suspect locations.

Each fastener hole containing a suspect flaw was identified with an engraved ID number and the clock orientation was punch-marked near the hole. After the sample pieces were marked for cutting and photographed, they were cut into smaller laboratory specimens containing one or more flawed fastener holes. Those specimens with a single hole measured 1 to 2 inches square. The larger specimens contained large flaws or more than one hole. The specimens were thoroughly cleaned using a mild alkaline solution followed by immersion in an ultrasonic cleaning tank containing acetone. At this point, the specimens were examined optically to determine the need for further processing.

SLIDE E4

DESTRUCTIVE INSPECTION

Those specimens whose flaws were obvious visually or when viewed with a binocular microscope having up to 30X magnification were opened for crack characterization without further processing. Otherwise, additional processing was necessary to determine the precise location of the flaw prior to opening the specimen. Processing now depended on whether the specimens still had an anodize layer at this point. Specimens from samples A, B and F had an anodize layer which now required stripping in an etch solution. Afterwards, an optical examination was made to cull the visually detectable cracks, which were opened *without further processing*. If a crack was not detected, the specimen was alkaline etched and deformed under tension if necessary until all flaws were identified and opened. Samples D and E had been previously etched prior to incorporation in the program to remove the anodize layer. Specimens from these were inspected using an eddy current bolt hole probe to pinpoint flaw indication. Then additional etching and optical examination, sometimes aided by flourescent penetrant, were provided as necessary to determine where the specimen should be opened. All the specimens were opened at suspect flaw sites. In some cases, the previous flaw indications were due to gouges and pitting, as in the case of sample D specimens, or to generally poor hole wall conditions. The presence of these noncrack flaws explains at least some of the "false calls" reported during the program.

Flaw size measurement on opened cracks larger than .010 inches were made with the use of a metal scale and a 30X magnification binocular microscope. Precision of the optical measurements was ± 0.005 with recorded values rounded to the nearest $0.\overline{10}$ inch. For flaws smaller than .010 inches, measurements were made using a graticule on a scanning electron microscope display. The precision was ± 0.0005 inches, rounded to the nearest 0.001 inch. Flaw plane angularity with respect to the flaw axis and the true radial direction were measured using a protractor overlay.

SLIDE E5

FLAW CATEGORIES

Categories for recording flaw types, dimensions, and angularity pertinent to the program specimens are shown here. Flaw types were categorized according to flaw location and configuration within the sample. Flaw dimensions were measured axially along the hole wall and radially from the hole edge. Dimensions and crack type were recorded. An angle A (alpha) was recorded for flaws whose axial dimension varied from the true axial direction. An angle B (beta) was recorded for flaws whose radial dimension varied from the true radial direction.

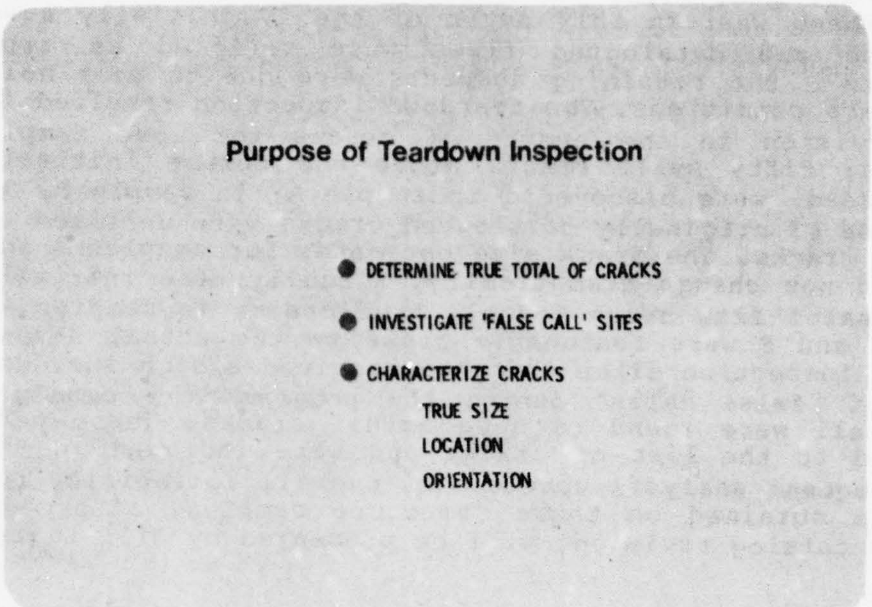
SLIDE E6

SUMMARY OF TEARDOWN RESULTS

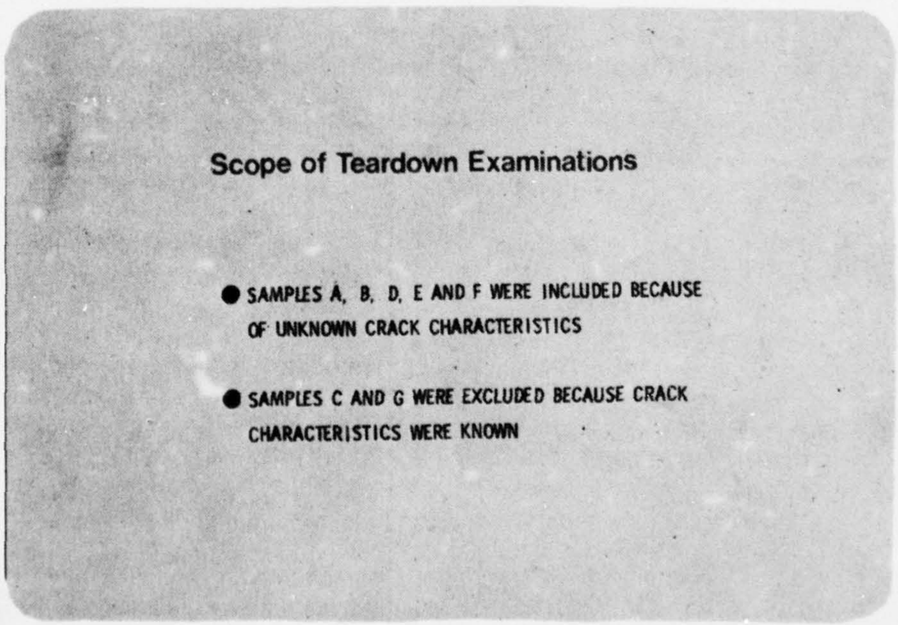
A catalogue of accurate crack dimensions was constructed from the teardown inspection data. These data were then available for use in analyzing the program results. Since complete flaw dimensions and shape information is available, cracks can be stated in terms of flaw area, flaw length or flaw aspect ratio. This was accomplished in order that flaw characteristics could be evaluated to determine their influence on detection and all "false call" sites could be resolved. In the case of sample D, flaws that were previously regarded as very small cracks were determined instead to be gouges and pitting, as Bill Lewis previously noted. Sample D, therefore, was eliminated from further analysis in evaluating the program results.

Much the same thing was experienced with the sample E specimens wherein only seven of the 27 initially suspected and catalogued flaws were verified as true cracks - the remaining suspects were due to poor hole surface conditions. The teardown inspection resulted in a revision in the number of cracks for some sample types; fifty small cracks above the number initially recorded, were discovered in sample A; in sample F, 34 of the 43 originally catalogued cracks were verified as true cracks. The crack size estimates for samples A and B did not change dramatically. Actually, the initially estimated flaw sizes for all true cracks in samples A, B, E and F were reasonable close to the actual sizes. Five inspection sites that had received a high incidence of "false calls" during the program were examined and all were found to have actual cracks. These were added to the list of cracks and were included in the subsequent analysis update. The overall reliability results obtained on these structure samples, after the flaw catalog revision, will be presented by Bill Lewis.

SLIDE E1



SLIDE E2



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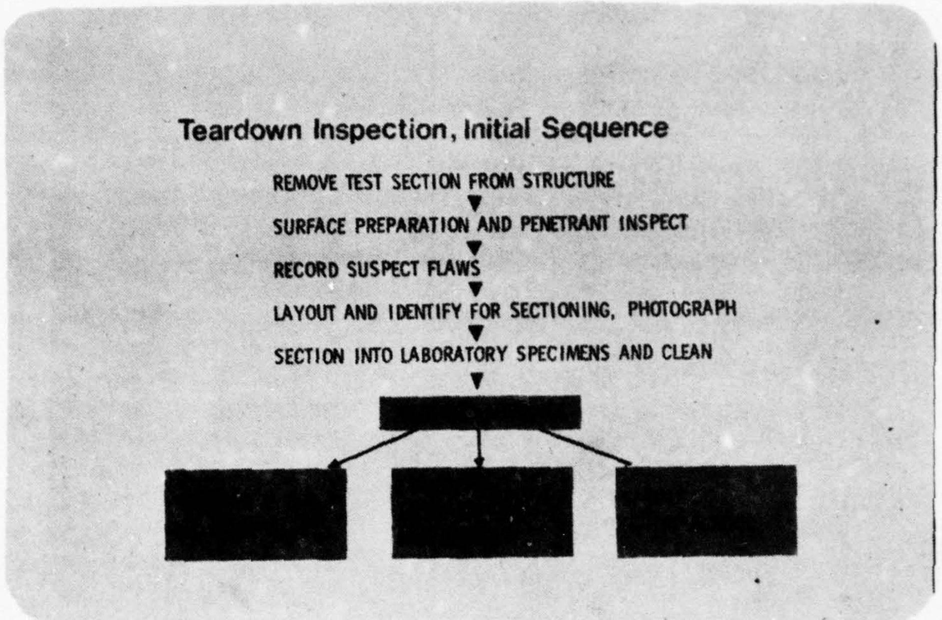
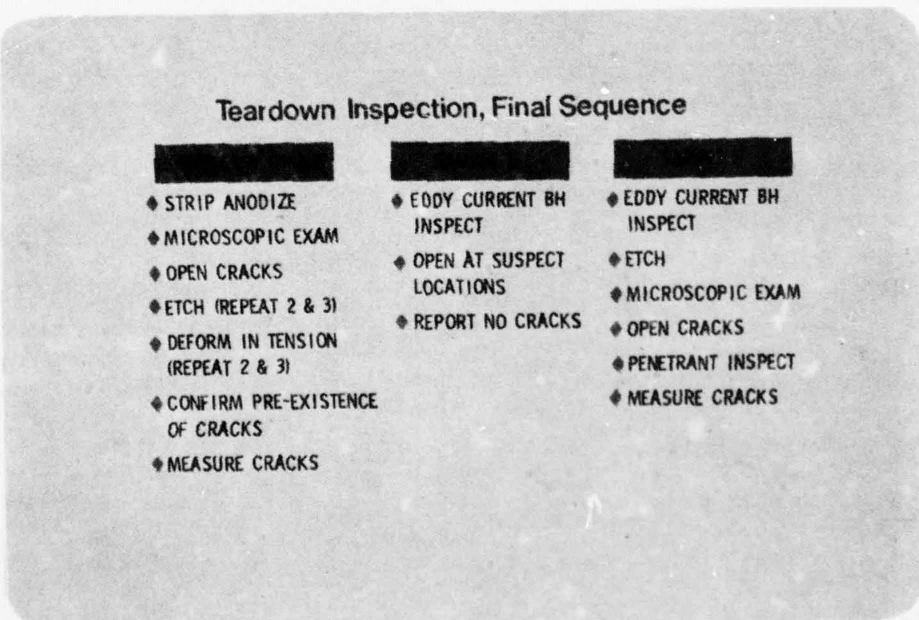
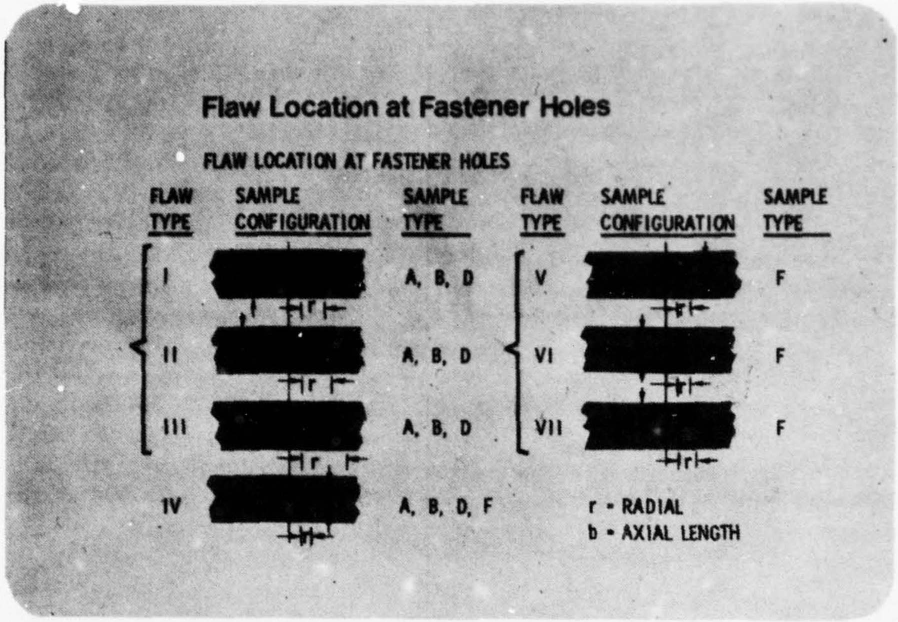


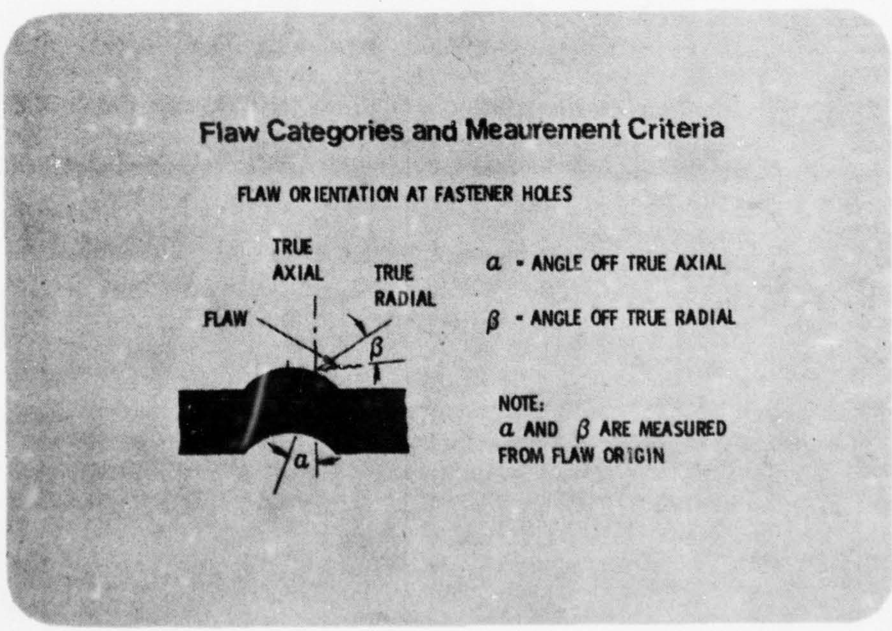
SLIDE E4



SLIDE E5



SLIDE E6



SLIDE E7

Summary of Teardown Inspection

- CATALOGUE OF ACCURATE DIMENSIONS AND CHARACTERISTICS FOR ALL FLAWS
- FIVE "FALSE CALL" SITES WERE RESOLVED AS ACTUAL CRACKS
- SOME PREVIOUS FLAW SITES ELIMINATED (SAMPLE D)

OVERALL PROGRAM RESULTS

SLIDE F1

I'm going to be showing you a series of slides next that display graphically the overall flaw detection capabilities that we observed during the program. Before we look at these slides however, it is extremely important to point out that generalizations cannot and must not be made from these overall curves. They represent the total flaw detection probabilities of all the 298 individual participants in the program measured under very specific conditions. We do not possess the knowledge or the experience that would allow us to translate these flaw detection results to any other specific set of inspection conditions. We do know, and these overall results show us, that a change in any of the parameters associated with a specific nondestructive inspection can have a dramatic effect on flaw detection probability.

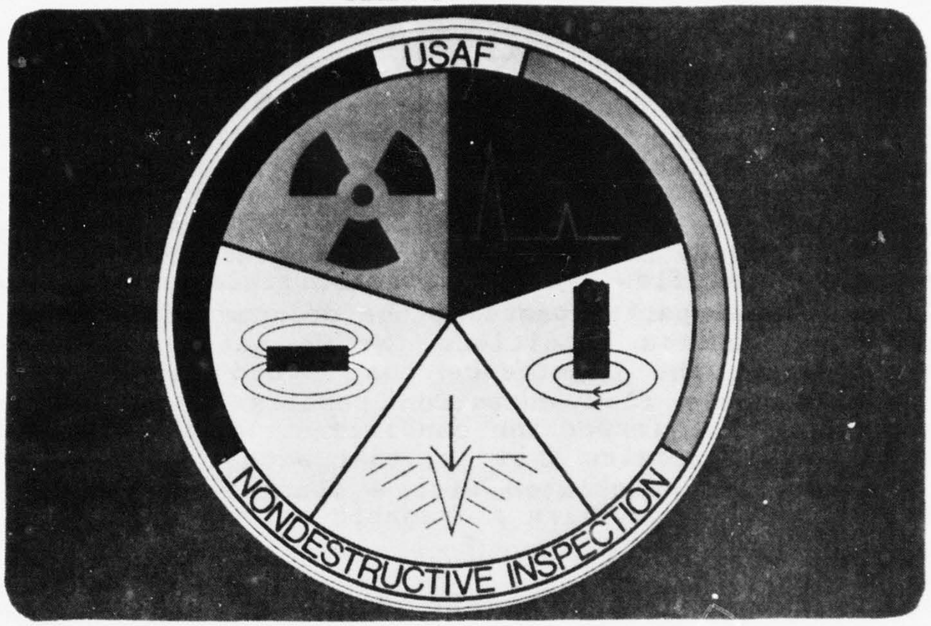
These curves do represent the overall crack detection capability of all the NDI technicians included in the program as measured under the specific sets of conditions noted. Statistically, they represent total Air Force capability at the present time under the same conditions, and they should be viewed in that context.

The curves are a regression fit to individual data points established by a large number of independent attempts to find each individual flaw. For each set of conditions, we have plotted the mean crack detection probability of all technicians vs crack size along with the lower 95% confidence bound to indicate the combined effect of data scatter and sample size on the statistical certainty of the measurements.

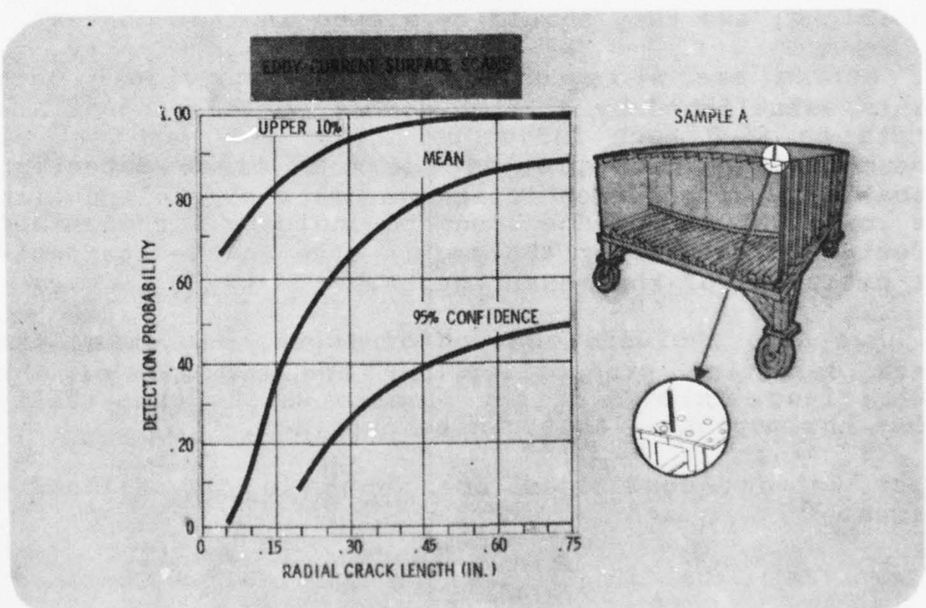
We have also included on each of these, a plot of the crack detection probability for the top 10% of the technicians included in the program which dramatically shows the potential that can be obtained.

These various conditions are shown in the following slides.

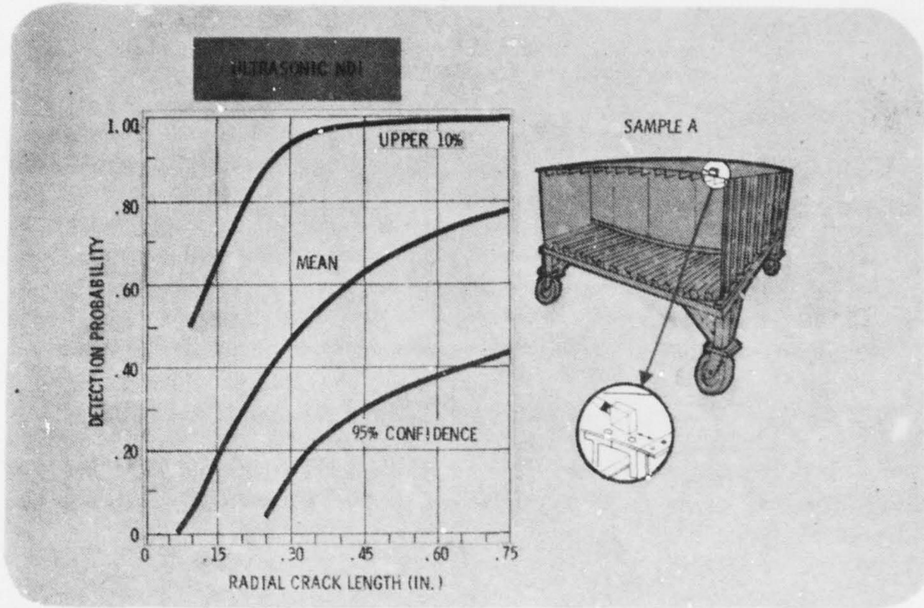
SLIDE F1



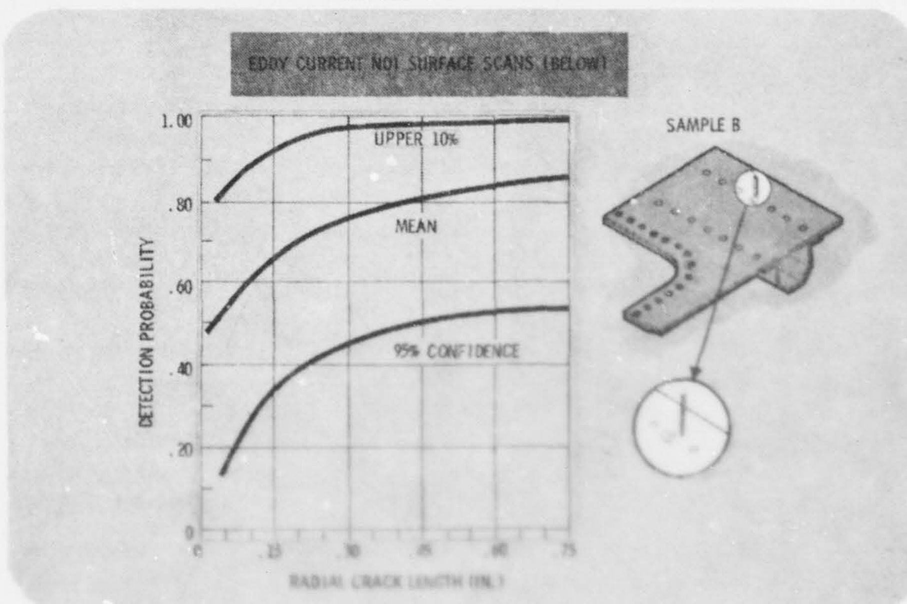
SLIDE F2



SLIDE F3



SLIDE F4



AD-A068 223 LOCKHEED-GEORGIA CO MARIETTA F/G 1/3
PROCEEDINGS FROM THE GOVERNMENT/INDUSTRY WORKSHOP ON THE RELIAB--ETC(U)
DEC 78 W H LEWIS, W H SPROAT, W M PLESS F41608-76-D-A005
UNCLASSIFIED LG78ER0261 SA-ALC/MME-76-6-38-2 NL

2 OF 4
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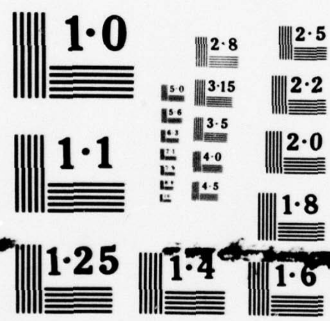
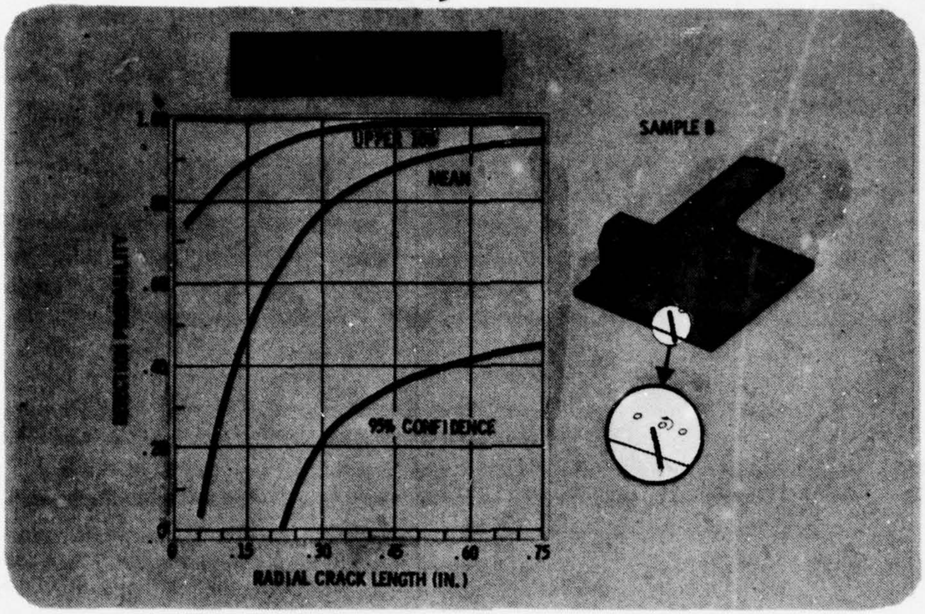
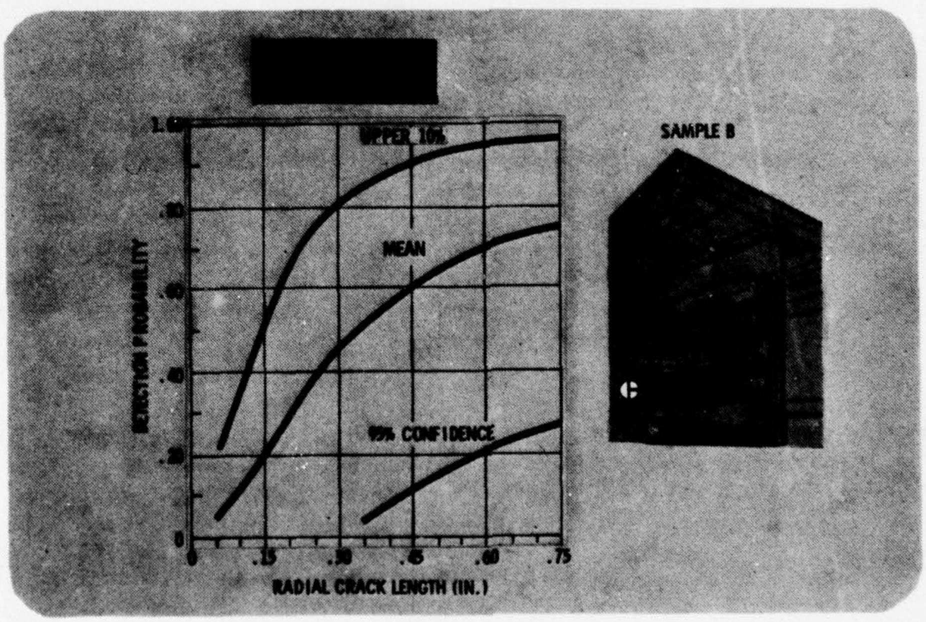


NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

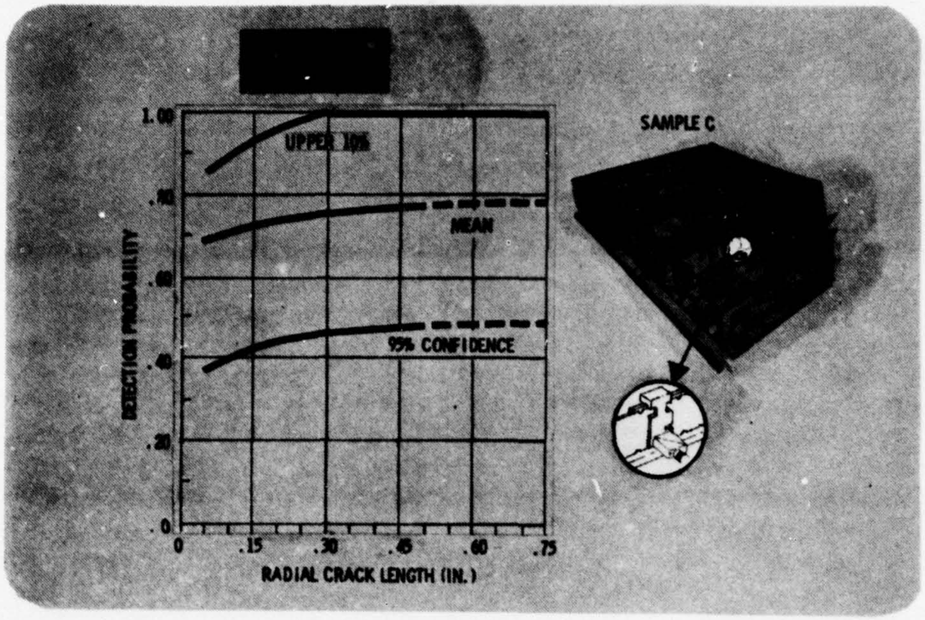
SLIDE F5



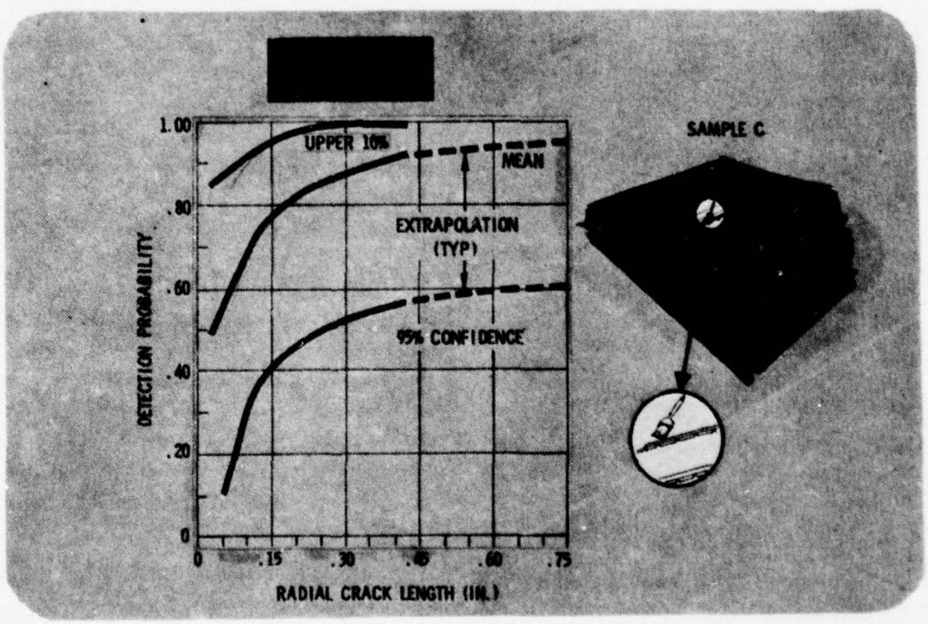
SLIDE F6



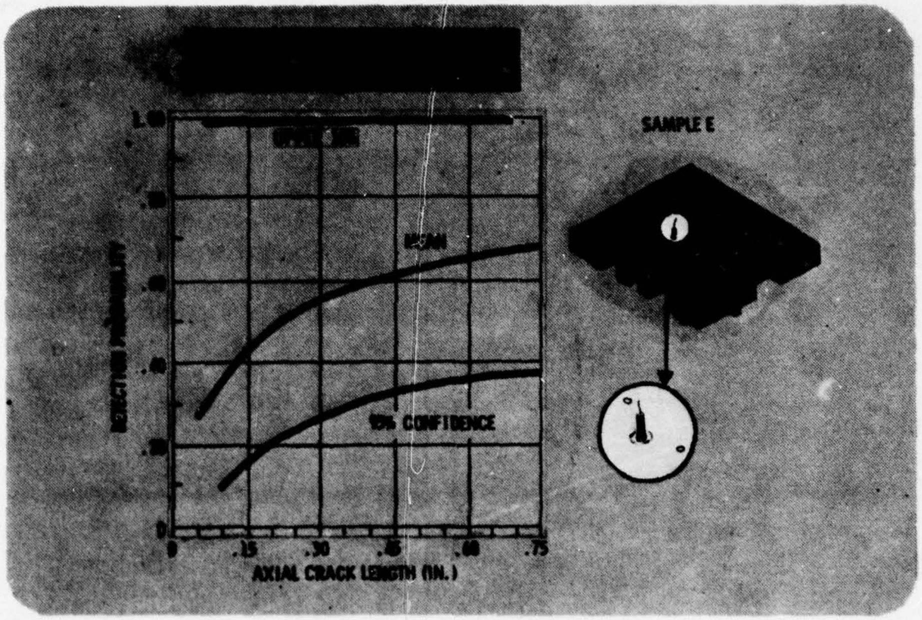
SLIDE F7



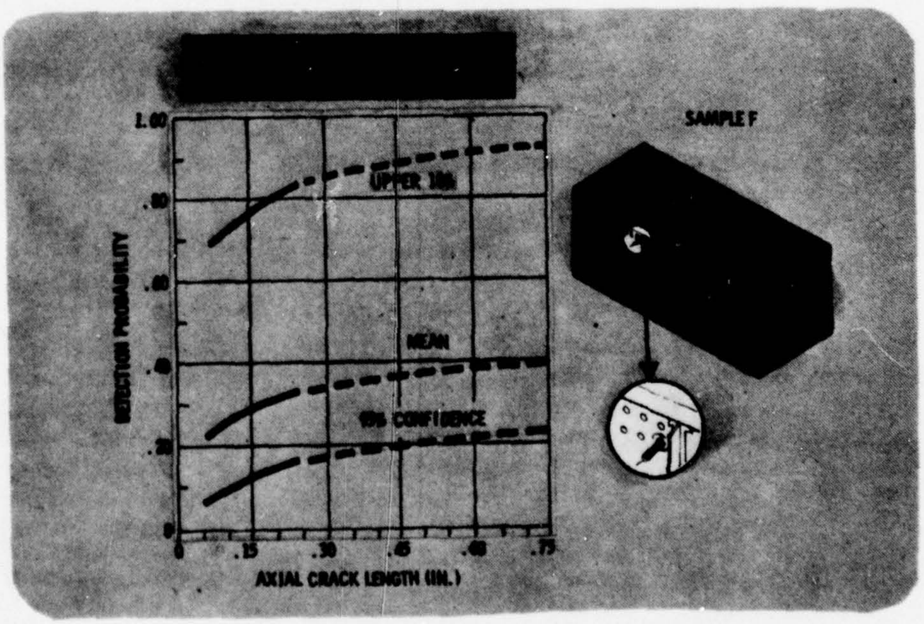
SLIDE F8

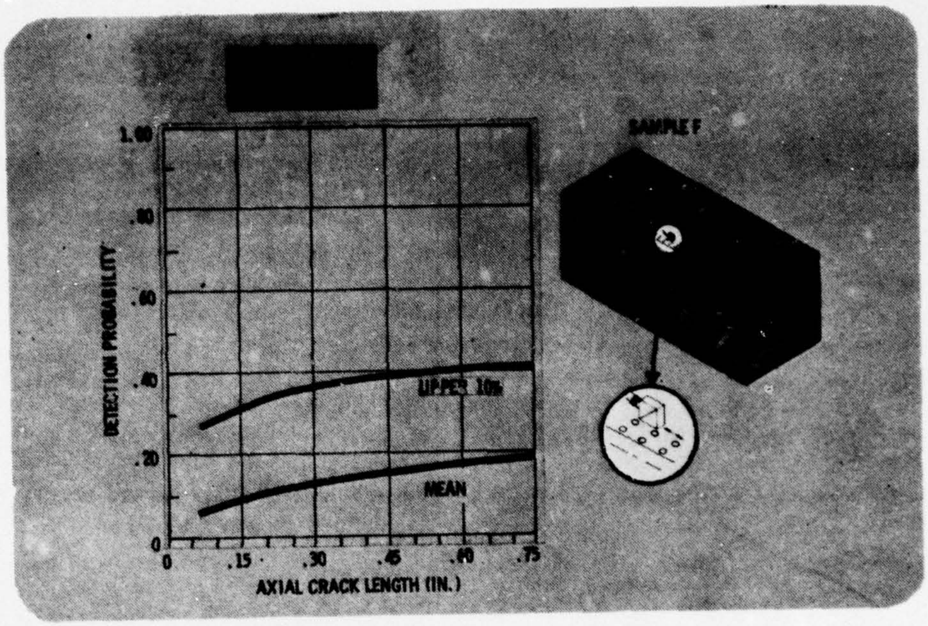


SLIDE F9



SLIDE F10




[redacted]
SAMPLE F
1.00
.80
.60
.40
.20
0
DETECTION PROBABILITY
UPPER 10%
MEAN
0
.15
.30
.45
.60
.75
AXIAL CRACK LENGTH (IN.)

PROGRAM ADDITIONS

SLIDE G1

Approximately half way through the data acquisition phase of our preliminary data, it was decided that this would be a golden opportunity to evaluate several recent improvements made in nondestructive testing methods. Specifically, these consisted of the automated eddy current bolt hole inspection equipment originally developed by the Sacramento Air Logistics Center and commercially marketed by Gulton Industries and also automated ultrasonic inspection equipment specifically designed for the inspection of the outer layer with the fastener installed. This equipment was originally developed by the Boeing Company under contract with the Air Force Materials Laboratory. The Gulton eddy current bolt hole equipment was very new at this point in time and was just beginning to be phased into the Air Force inventory, therefore we carried it with us. In order to acquire data on its use and a measure of the resulting improvement in detection reliability accorded by such equipment, it was decided to incorporate it as soon as possible in the Reliability Measurement Program.

SLIDE G2

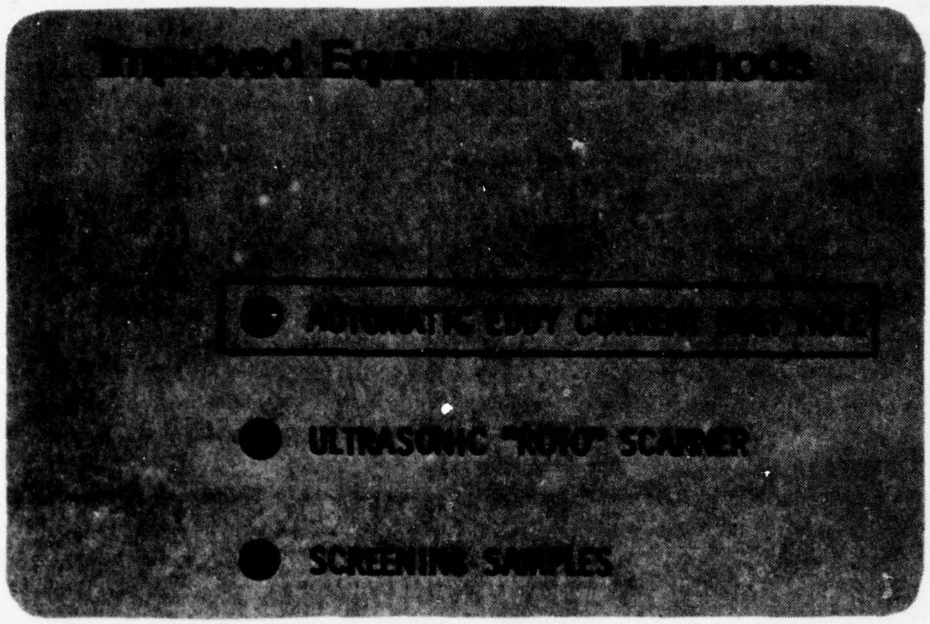
On the the other hand, the automated ultrasonic roto-scan equipment existed only in various prototype stages and a version of the prototype equipment was included in our program in order for us to get a similar cursory evaluation of its crack detection capability.

SLIDE G3

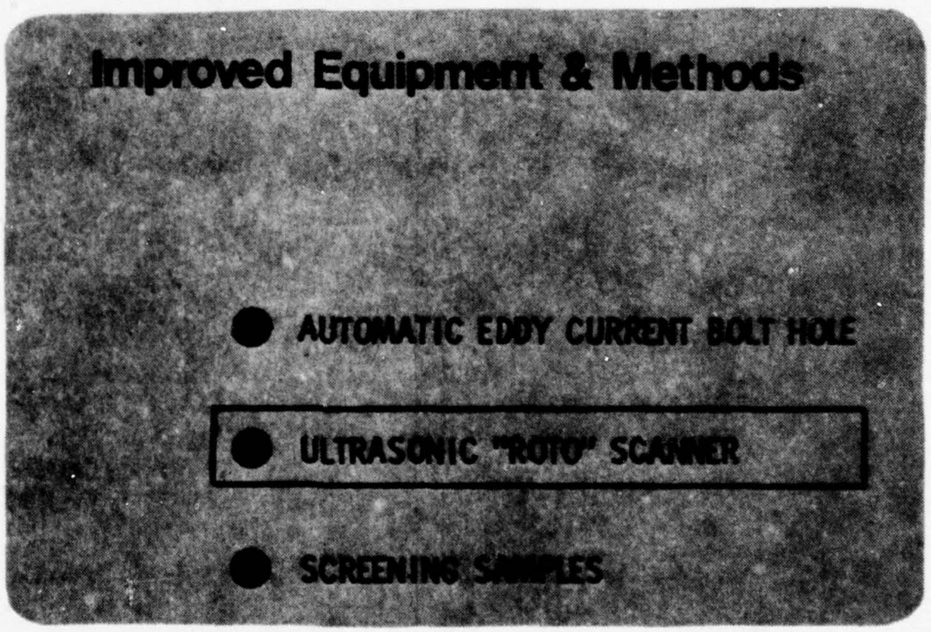
Besides these two additions, a third addition to the program was made during this period which was funded by the Air Force Materials Laboratory and consisted of some flat plates with fatigue cracks originating from the fastener holes in these plates. The purpose of this addition was an attempt at determining if a measure of technician proficiency in detecting cracks could be obtained from inspections made on a few simple reproducible flat plates instead of the much more expensive

unreproducible and time consuming complex structure. If such a correlation between the flat plates and the complex structure exists, then the results are obvious. These flat plates added to the program became known as the technician screening samples. We plan to cover each one of these additions to our basic program in more detail because we feel that each provided us with a valuable insight and important results that can be applied to other areas for improvement purposes. Bernie Boisvert from the San Antonio Air Logistics Center will now briefly describe for you the automated eddy current bolt hole inspection equipment and the results we obtained from using it.

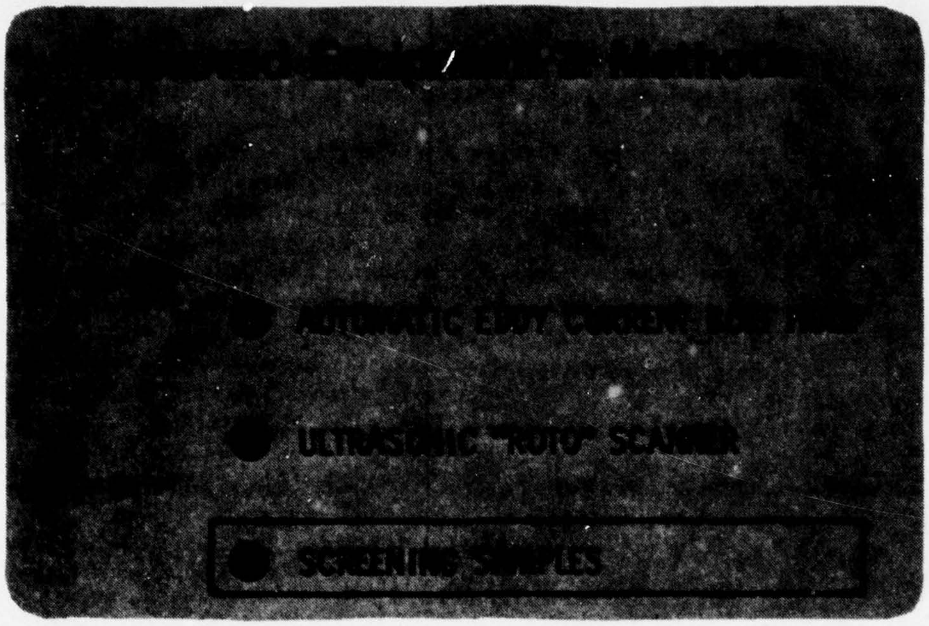
SLIDE G1



SLIDE G2



SLIDE G3



PROGRAM ADDITIONS - AUTOMATIC EDDY CURRENT

SLIDE H1

The eddy current inspection method is currently accepted as one of the most potentially reliable and repeatable methods in the aircraft NDI repertoire. It is simple to apply and often requires less surface preparation than other comparable methods. It usually does not require a precise prediction of where the flaw will occur as does the ultrasonic method.

The eddy current method can be applied in various ways, which include both hand scanning and automated scanning. It can be applied to planar or contour surfaces and to small-diameter fastener holes.

Today, I want to discuss an application of the method to the inspection of fastener holes, for this is a critical application for which significant advances in eddy current instrumentation have come about in recent years.

SLIDE H2

One disadvantage of the eddy current method for bolt hole inspection has been the lack of repeatability and reliability of inspection results when hand scanning techniques are used. Hand scanning is highly operator dependent and results can vary considerably from one inspector to another. This is because the quality of hand scanning depends on the operator's skill, his understanding of the specific problem, his physiological motor functions and additional factors that can be highly variable and unpredictable.

There was a need to remove as much of the operator-dependency as possible, in order to exploit more of the method's inherent sensitivity and reliability. This could be done by making certain changes to eddy current equipment involving an automated scanning head and a way of presenting the inspection information that would be less dependent on "transient eyeball judgement."

SLIDE H3

In 1970, an automated eddy current bolt hole system was developed at McClellan Air Force Base, California, resulting in the prototype shown here, which was used on the F-104 aircraft.

The system consisted of a motorized scanner to hold, rotate,and spirally index the bolt hole probe into and through the bolthole. A Magnaflux ED-520 was used as the electronic heart of the system. A strip chart recorder provided a permanent record of the indications as produced in the ED-520 plus a rotation marker. The scanner and recorder were controlled by switches on the control panel. Various hardware was included for calibrating the system and rigidly mounting the scanner to the part being inspected, which, in the initial case, was the F-104 wing. The entire system was transported and used in a single case.

SLIDE H4

This system was somewhat cumbersome in its overall size and in the necessity to mount the scanner on the part being inspected. Also, because it was initially dedicated to the F-104 problem, it had some minor limitations relative to other applications. Hence, it was not suitable for general widespread field use.

SLIDE H5

During the next several years, simultaneous improvements were made by various individuals to produce a hand-held portable system for field inspections. A meeting was held at Kelly AFB in February 1974 to evaluate three different systems developed by three separate organizations: Gulton Industries, the Lockheed-Georgia Company, and Oklahoma City Air Logistics Center (ALC). The Gulton Industries FD-222, which was evaluated, is shown in this slide.

SLIDE H6

The Lockheed version that was presented for evaluation at that time is shown here.

SLIDE H7

The model FD-100, made by Gulton Industries, now currently in use at several Air Force installations, resulted from the recommendations and specifications at this meeting. The use of the Gulton FD-100 currently appears in the AFTO-36 NDI manuals for various aircraft. The FD-100, as you can see here, has essentially the same basic elements as the original McClelland prototype, but is considerably moreunitized and portable.

SLIDE H8

The automated probe head of the FD-100 does not require mounting to the part being inspected. It is hand-held against the part while the probe's spiral rotation into or out of the fastener hole is conveniently controlled by a rocker switch on the probe head. Probes are interchangeable and are made especially for the unit with common threaded connectors.

SLIDE H9

The FD-100 is convenient for field use. Its size and weight make it easily portable and useful under a wing or other space-restricted area. The fact that a recording is made of the eddy current indications eliminates the need for the inspector to try to keep one eye on the probe and the other eye on the meter - now he can observe the probe and read the recording later. If he is not satisfied with the quality of the indications, he can make the changes he thinks necessary and repeat the hole-scan. Recordings of each hole he "inspects," including the standard, can be kept in the permanent files. Obviously, great improvements in reliability and data analysis are inherent in this type of system.

The automated eddy current bolt hole system has not replaced the manual scan system - both are now used in the Air Force and commercial aircraft maintenance. Therefore, it was highly desirable to incorporate an evaluation of the FD-100 system into the ongoing NDI Reliability Measurement Program, where the results could be compared directly with the manual scan

results. The automated system was not initially included in the "Have Cracks" program because the system was not generally available at Air Force installations.

SLIDE H10

Two FD-100 systems were purchased and they were incorporated into the program at Dover AFB in December 1976, and used throughout the remainder. Lockheed supplied step-by-step self-training procedures, practice samples and inspection procedures for using the system on the program samples. The self-training procedures and practice samples, shown here, offered a means to familiarize the Air Force technicians with the operation and use of the FD-100 prior to applying it to the structure samples, since most technicians would not have experience in using it previously.

SLIDE H11

The FD-100 automated bolt hole system was used on structure type D, shown here, and ......

SLIDE H12

structure type F (shown here). Since, manual bolt hole inspections were also made on these structure types. We can compare the results of both types of eddy current inspections on the same type structure samples.

SLIDE H13

This slide shows the results for structure sample E in terms of the mean and 95% confidence curves. In addition to a greater overall percentage of detection, we see a noticeable improvement in detection of the cracks below 0.20" axial length. The "manual" data were accumulated from all 21 of the Air Force bases and the "automatic" data were collected from 9 bases. These included 105-1/2 and 21-1/2 inspection tasks, respectively.

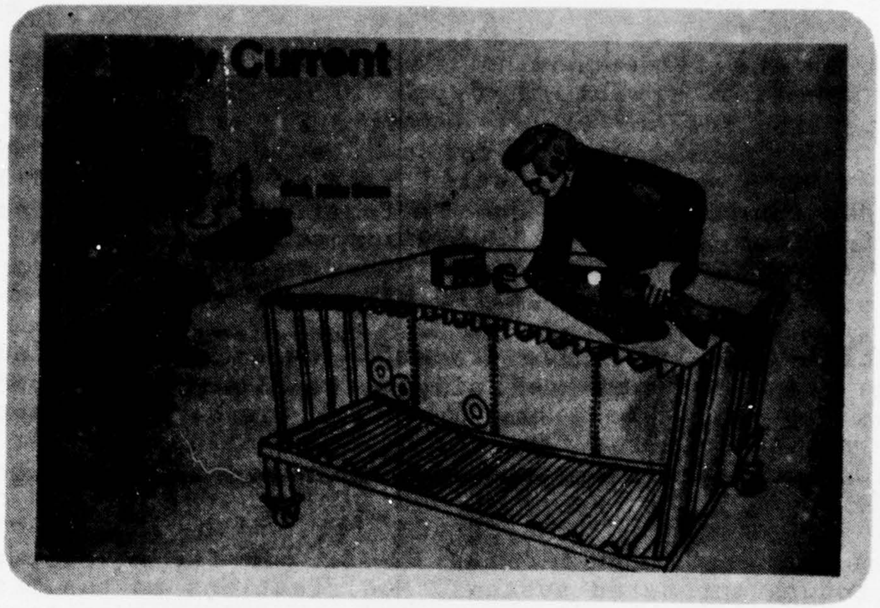
SLIDE H14

Next is the slide showing the "manual" and "automatic" results for structure type F. The improvement in inspection reliability is dramatic for this application for all crack sizes in the sample. The "manual" data for sample F were collected from 19 bases in 76-3/4 inspection tasks and the "automatic" data were collected from 7 bases in 13-1/2 inspection tasks.

SLIDE H15

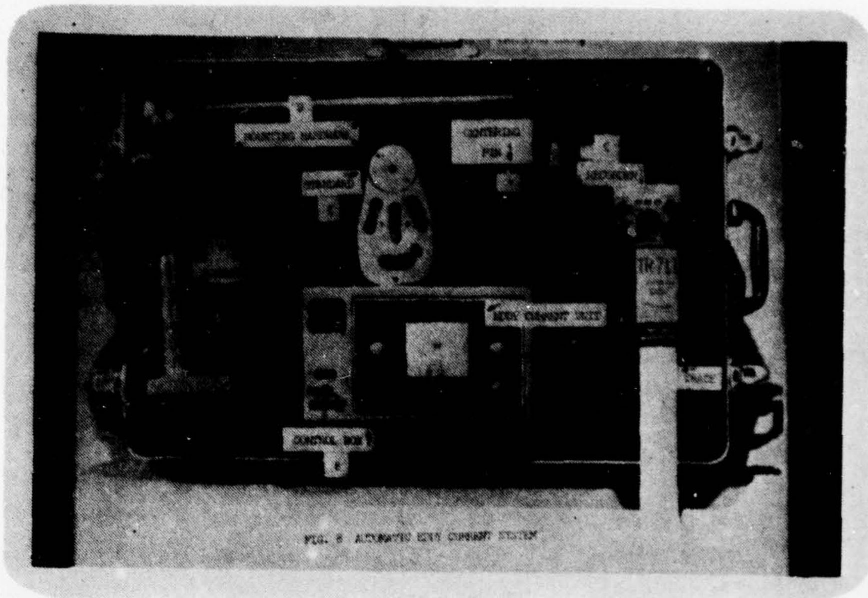
Results from the "Have Cracks" program strongly indicate that the automated eddy current bolt hole system does indeed increase the potential for higher inspection reliability for fastener holes. I believe a fair comparison between manual and automated units has been made in the two applications just shown. This final slide summarizes the factors for which improvements have been required for the FD-100 and for development of future automated systems. Modifications to the basic system are continually being made to bring about incremental advancements in these factors to improve operating characteristics and crack detection capabilities.

SLIDE H1

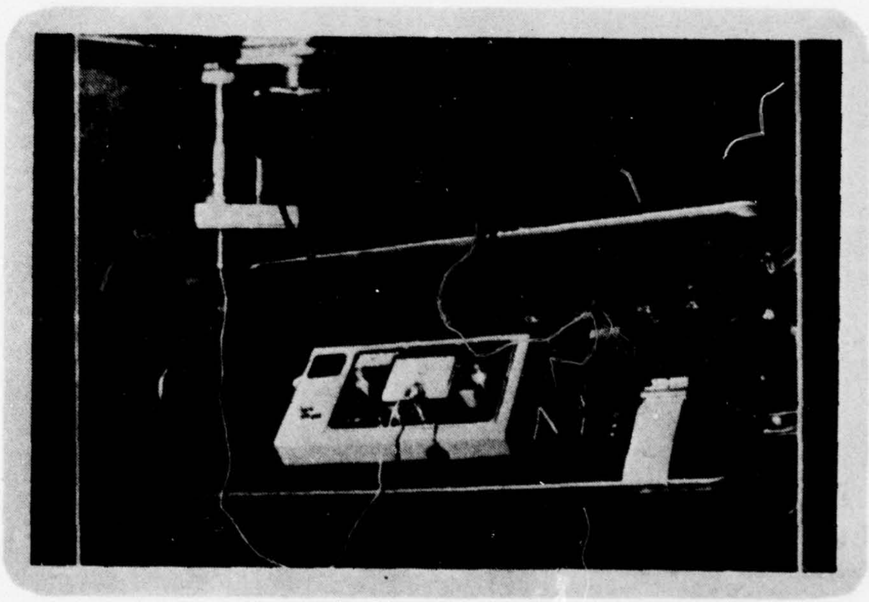


SLIDE H2

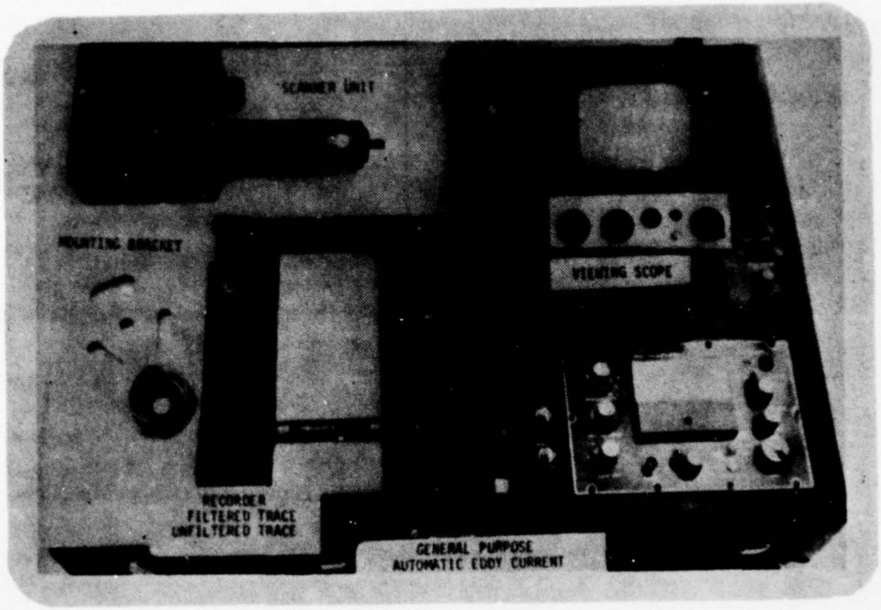
SLIDE H3



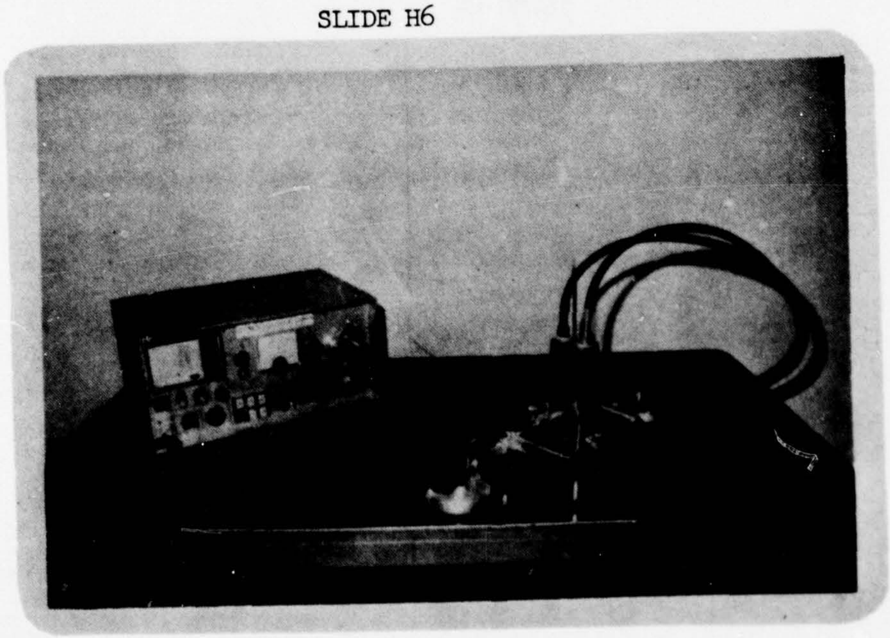
SLIDE H4



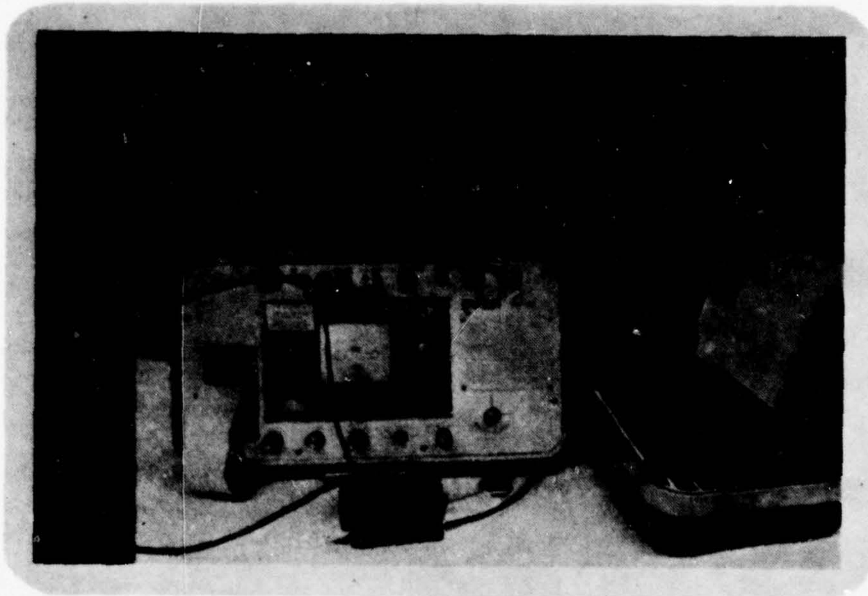
SLIDE H5



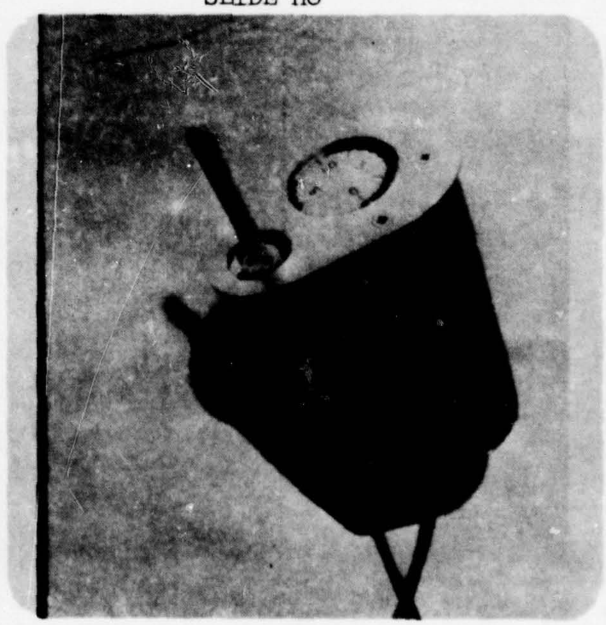
SLIDE H6



SLIDE H7

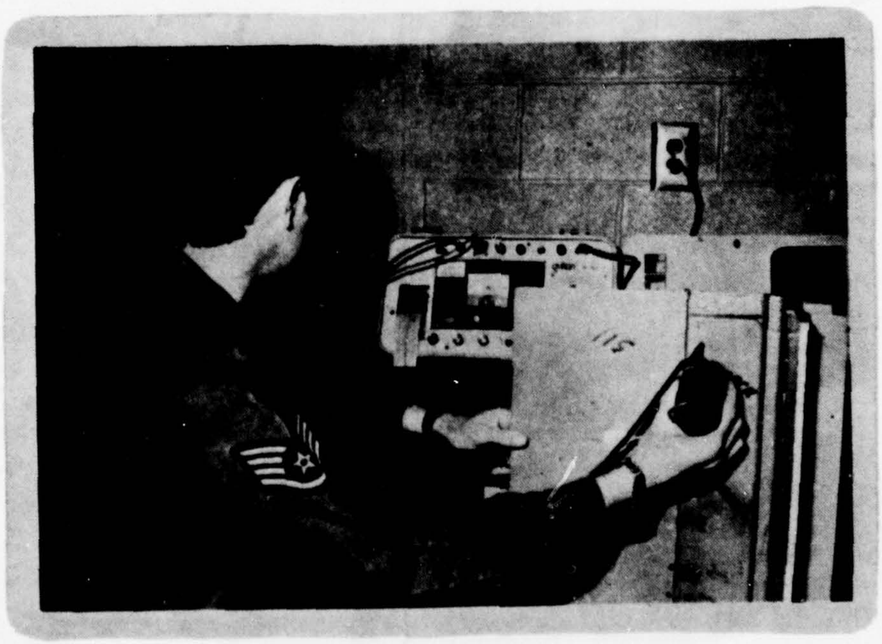


SLIDE H8



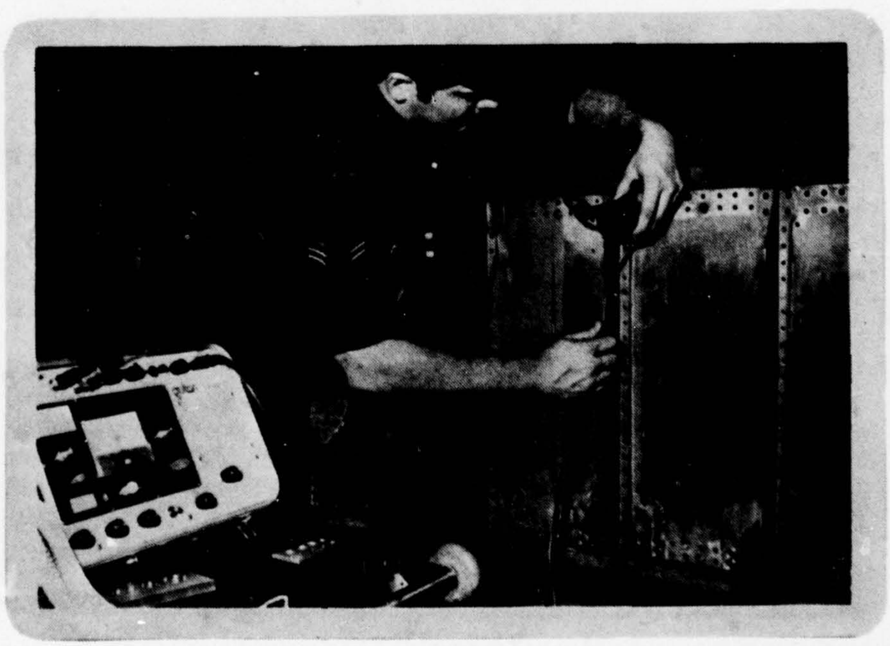
SLIDE H9

SLIDE H10

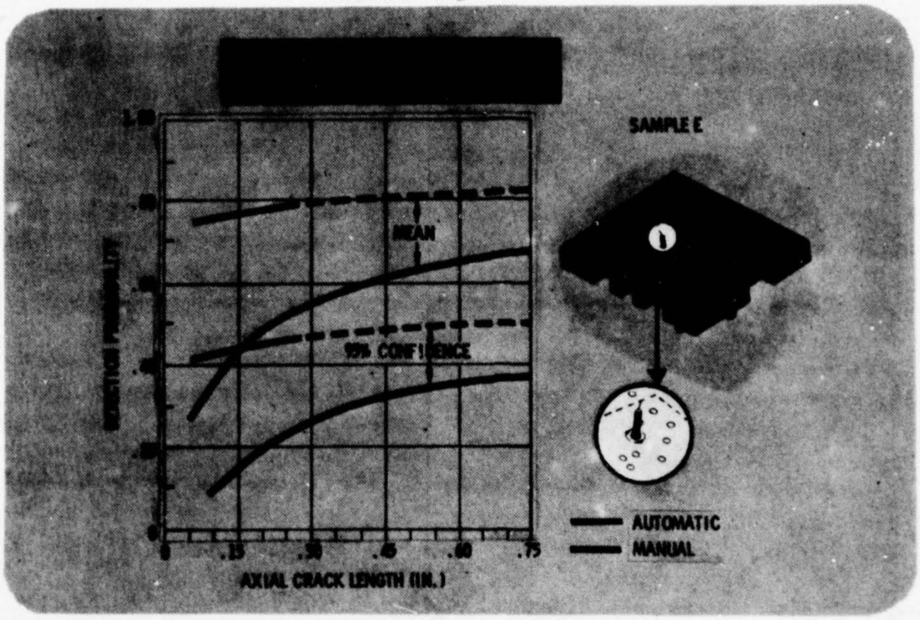


SLIDE H11

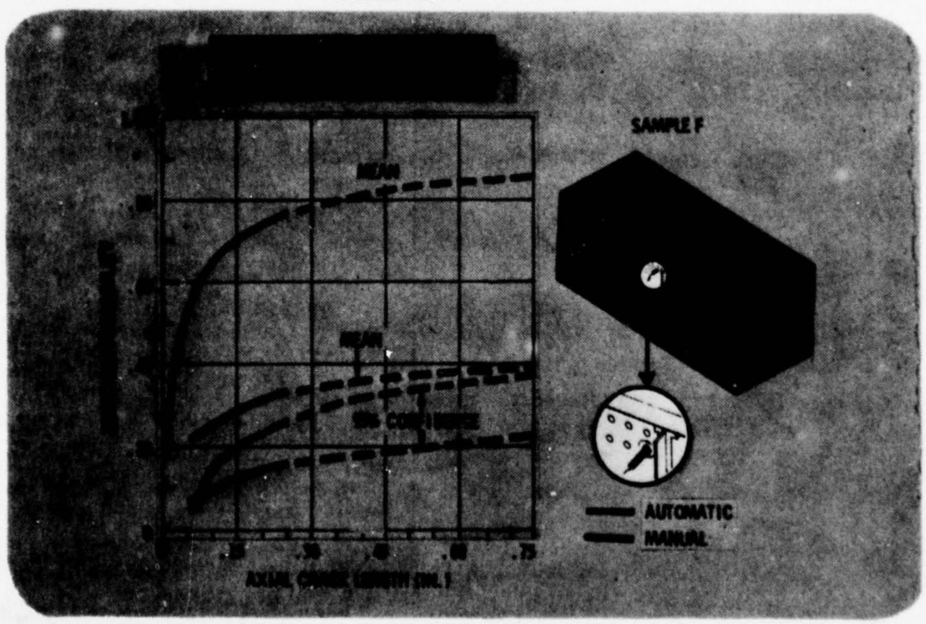
SLIDE H12



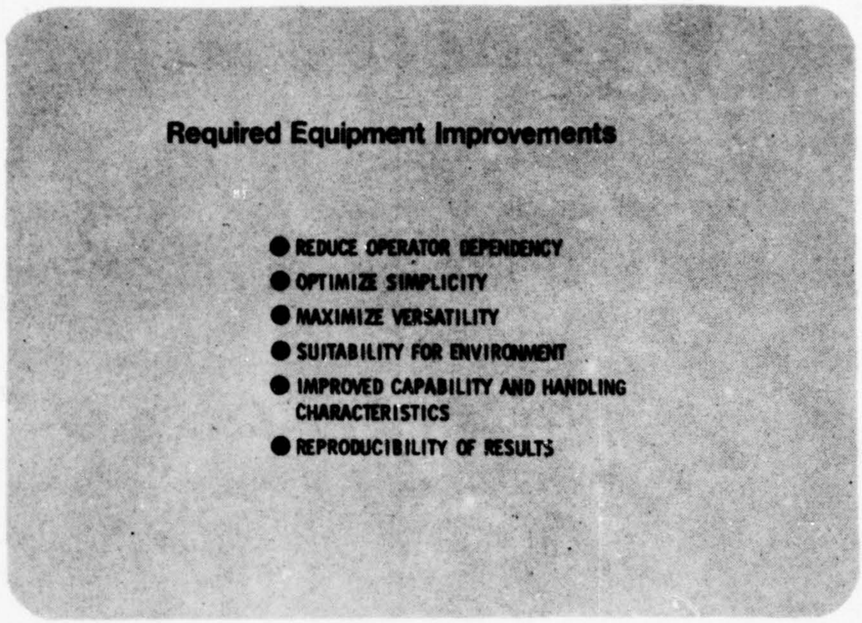
SLIDE H13



SLIDE H14



SLIDE H15


Required Equipment Improvements
● REDUCE OPERATOR DEPENDENCY
● OPTIMIZE SIMPLICITY
● MAXIMIZE VERSATILITY
● SUITABILITY FOR ENVIRONMENT
● IMPROVED CAPABILITY AND HANDLING CHARACTERISTICS
● REPRODUCIBILITY OF RESULTS

PROGRAM ADDITIONS - ULTRASONIC "ROTO-SCANNER"

SLIDE I-1

As you have seen from the previous presentation, once the fastener has been removed from the fastener hole, eddy current bolt hole inspection provides us with a very good practical method for detection of fatigue cracks. It is however, often undesirable or even impossible to remove fasteners in order to gain access for an eddy current bolt hole inspection. This is especially true where interference fasteners are concerned. The removal and replacement of interference fasteners are not always easy and the risk is ever present that damage to the hole or the fastener may result. Therefore the need has existed for some time for a practical means of inspecting fastener holes without fastener removal.

A number of interesting approaches have been proposed and investigated to varying extents including acoustic impact, ultrasonic, and both low frequency and multi--frequency eddy current. The acoustic impact technique was pursued during the late 60's and proved to be highly sensitive to a wide range of variables inherent in aircraft construction which inhibited fatigue crack detection. Both the low frequency and the multi-frequency eddy current approaches are still under development to improve resolution although several low frequency eddy current instruments are already on the market and being used in some applications.

The ultrasonic approach is limited to positive interrogation of the outer layer of a joint as the energy will not always penetrate the faying surface to subsequent layers. In spite of this limitation, however, ultrasonics does have the potential for detecting very small cracks under countersunk fastener heads, along the hole wall, and at the faying surface of the outer layer. Sometimes it's possible to penetrate through to the inner layer and detect cracks there also. It was for these reasons that the Air Force Materials Laboratory actively pursued the development of a semi-automatic ultrasonic approach for the detection of cracks under fastener heads.

SLIDE I-2

Under contract from the Materials Laboratory, Boeing developed a working model of such a device in 1975. This equipment, which later became known as the Boeing "Roto-Scanner", as shown in this slide is being evaluated by Boeing engineers on the spanwise splices of the C-5A full scale fatigue test article.

SLIDE I-3

The Roto-Scanner had several very important advantages. It provided a highly stable and accurate means of positioning and rotating the transducers around the fastener head. The transducers were extremely accurate and the boots or shoes used to couple energy into the work piece was very efficient and allowed for smooth transducer rotation with no accompanying couplant problems. Manual manipulation was eliminated, providing a smooth, continuous scan around the fastener head circumference.

There were some distinct limitations to this early equipment, however, and some improvement was obvious.

SLIDE I-4

Four more of these early prototype devices were built by Boeing with some improvements for evaluation purposes. As a result of these evaluations, several different organizations began making their own improvements to these units or building their own version of the Roto-Scanner. Consequently, there are a number of slightly different Roto-Scanners at various locations around the country today, most of them slightly different and unique from all others.

During the time when everyone was making their own modifications to the Roto-Scanner concept, it was determined advisable to include a Roto-Scanner into the on-going NDI reliability program in order to obtain a measure of its effect on inspection reliability. The particular edition of the Roto-Scanner selected for inclusion in the program is shown in this slide, and was built by the San Antonio Air Logistics Center. It features a hand rotating knob which replaced the motorized mechanism of the earlier models.

SLIDE I-5

The precise position of the transducers was controlled by using templates as shown in this slide in order to accurately direct the narrow beam of sound energy to the desired location depending on the size fastener hole and sheet thickness being inspected.

Scans around fasteners were made using one transducer at a time with one full clockwise rotation on one transducer and one full counterclockwise rotation on the other. A UM-775 Reflectoscope with a Transigate alarm was used as instrumentation for the flaw detection. Echo signals occuring within a narrow gate set-up on a reference standard, triggered the alarm at 50% of full screen height.

SLIDE I-6

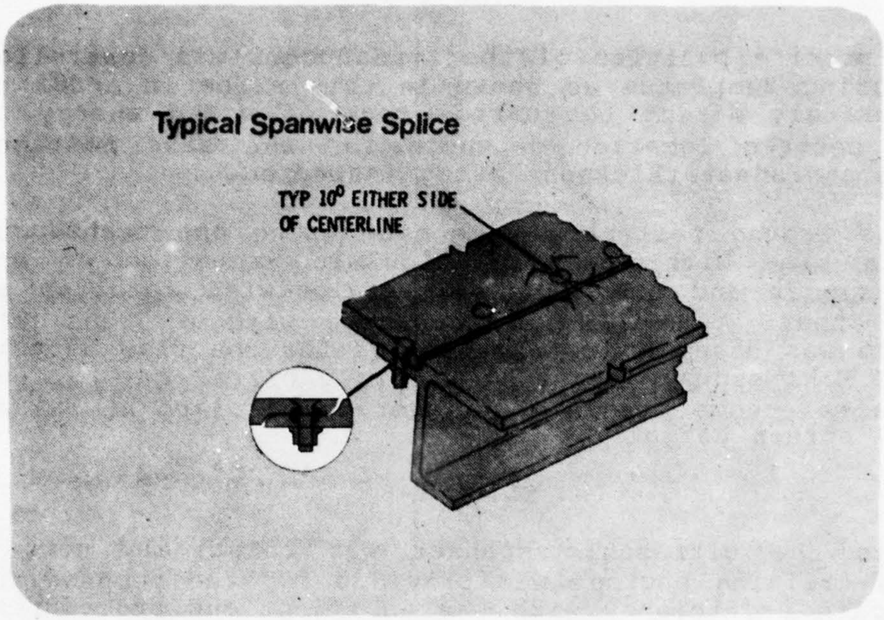
Since the ultrasonic scanner was relatively new, a self-training package was provided for the technicians to gain proficiency with the equipment and procedures. This package contained step-by-step instructions for set-up and operation along with pieces of structure containing identified flaws. Illustrations of the instrument response on these flaws allowed the operator to determine how correct operation was obtained. After a few days of training and familiarization with the equipment on structure samples having real cracks, the technician was ready to test his proficiency on the program samples.

SLIDE I-7

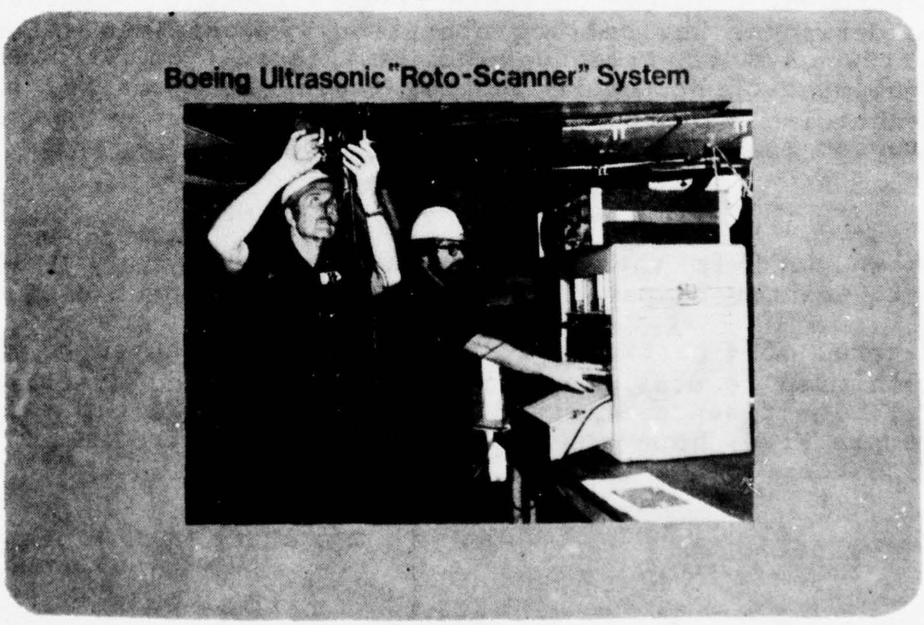
Shown here is the improvement obtained by using the Roto-Scanner compared to hand scanning on Specimen A.

A total of 4 participants at 3 bases contributed to the data used to draw the curve. There can be no statistical significance attached to this because of the small sample size; however, the potential for improvement is dramatic.

SLIDE I1



SLIDE I2



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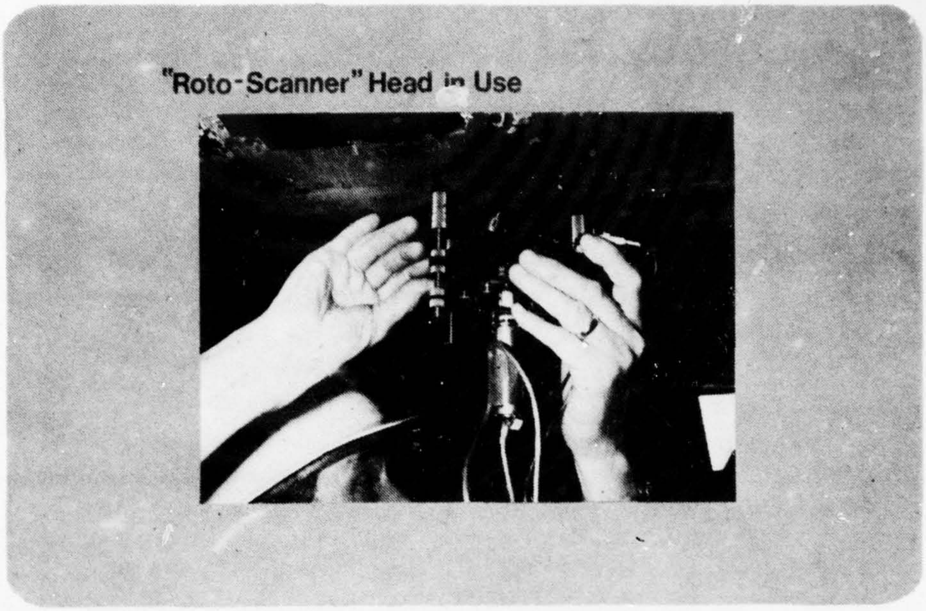

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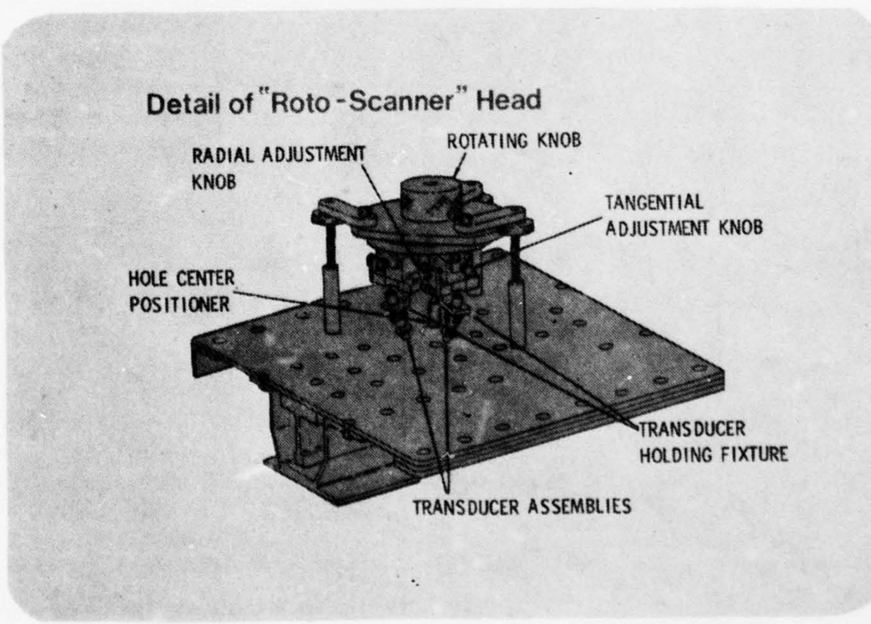

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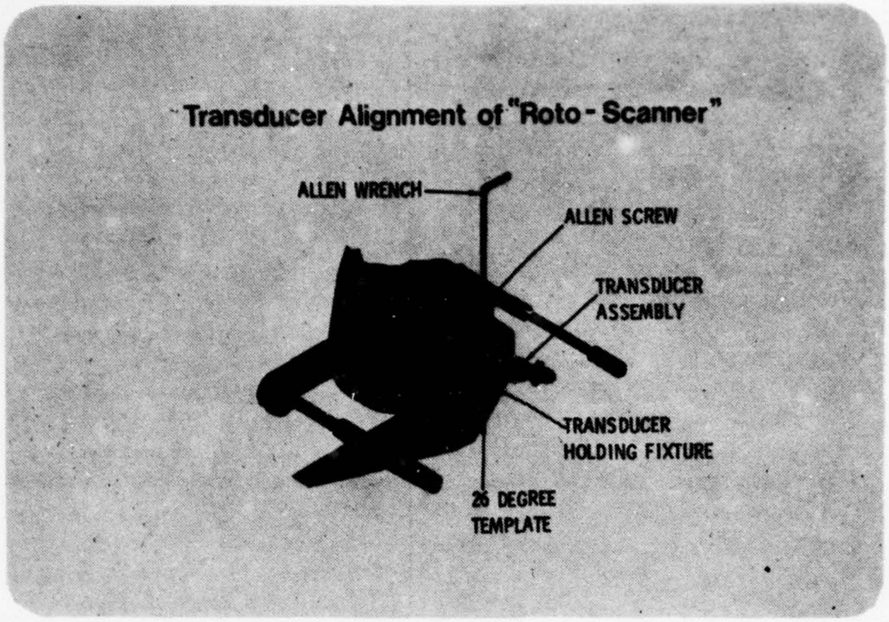


SLIDE I6

Self-Training Program

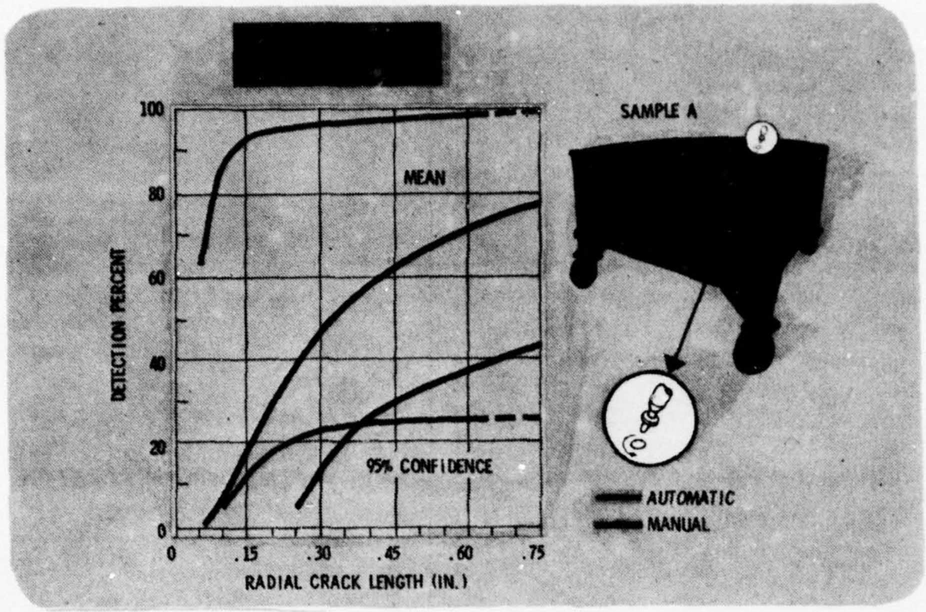
PURPOSE:

- FAMILIARIZE TECHNICIANS WITH "ROTO-SCANNER" USE

SCOPE:

- PRACTICE SAMPLES
- EQUIPMENT
- INSTRUCTIONS
- PROCEDURE

SLIDE I7


SAMPLE A
MEAN
95% CONFIDENCE
DETECTION PERCENT
0
20
40
60
80
100
0
.15
.30
.45
.60
.75
RADIAL CRACK LENGTH (IN.)
AUTOMATIC
MANUAL

PROGRAM ADDITIONS - TECHNICIAN SCREENING SAMPLES

SLIDE J-1

A preliminary evaluation of overall Air Force NDI capability was made after data had been collected from the first ten Air Force bases in the NDI Reliability Measurement Program. This evaluation tended to verify an earlier assumption that the proficiency of Air Force NDI technicians would vary over a wide range. Furthermore, the performance of a few individual technicians on the samples in the NDI program was quite poor, while performances of some others were outstanding in comparison.

It was feared that the same range of proficiency is experienced when technicians conduct inspections on flying aircraft. Of course, we always desire to have the best performance possible whenever inspections are conducted on actual aircraft hardware.

The idea evolved that perhaps the proficiency of NDI technicians could be determined through the use of screening samples containing real fatigue cracks. Technicians would be subjected to tests wherein they would inspect a very large number of sites, some of which would contain actual fatigue cracks. An analysis would be made of the results of individual technicians' performance to provide a picture of their inspection reliability. These analyses would be compared to the <u>same</u> technicians' performance on the program structure samples to determine the validity of judgements made based on the predictions of simple flat plates. Subsequently, an experimental screening program was designed by Lockheed and integrated into the "Have Cracks" program. The screening program was funded by the Air Force Materials Laboratory and implemented through the Air Force Logistics Command program with Lockheed.

I must point out that no one was certain that such a screening program would provide valid results for the purpose intended. It was completely experimental. We wanted to determine if it were possible to measure NDI capability using flat panels and test samples rather than actual aircraft structures. It if proved to be

possible, I think it is clear what the subsequent benefits would be in training and testing NDI technicians and in selection of high performance technicians to conduct critical inspections. The screening program was designed to help us determine that possibility.

SLIDE J-2

The screening program logistics consisted of 78 flat plate specimens which includes one standard, specimen holding fixtures, ultrasonic and eddy current bolt hole NDI procedures, specimen scoring sheets and technician evaluation sheets.

SLIDE J-3

The screening specimens were made from 7075-T6 aluminum alloy flat plate blanks measuring 2" wide by 16" long and 0.20" thick. Each specimen contained ten drilled and countersunk 11/64-inch diameter holes. Initially, smaller diameter pilot holes were drilled in 70 of the blanks which would contain cracks. Cracks were grown from starter notches in the pilot holes using a fatigue machine. Of the 770 holes which would be available as inspection sites, 123 of them would contain cracks. The cracks were grown in 70 of the samples as follows: 27 samples contain only one crack, 33 samples contain two cracks and 10 samples contain three cracks. The cracks were randomly distributed among the holes. Seven specimens contained holes without cracks. Cracks were grown in lengths providing four size ranges after drilling the holes to final size. The four crack length intervals were 0.050 to 0.100, 0.101 to 0.175, 0.176 to 0.250, and 0.251 to 0.350.

Each sample was serialized on one end with an identification number. Also each hole in the sample was identified with a digit from 0 to 9. Final preparation included painting with one coat of epoxy primer plus one coat of polyurethane enamel, then reaming the holes to 0.191 inch diameter and countersinking. Following this, the specimens were inspected with ultrasonic, eddy current and visual techniques to assure detectability of the cracks with the NDI techniques provided, but undetectable with the unaided eye.

SLIDE J-4

Data sheets for technician reporting of inspection results contain scaled drawings of each specimen with provisions for recording the specimen identification. The technician simply marked the hole where he found a crack and the position of the crack on the chart.

SLIDE J-5

A form was used by the Lockheed test monitor accompanying the program for grading the results of the technician's performance on the samples. These forms listed each crack by hole and specimen number, crack size range, and additional information about the inspector, the test site and NDT method. Columns were provided for recording whether the technician found or missed each flaw.

SLIDE J-6

Relatively easy, straightforward inspection procedures were provided the technician with step-by-step instructions for performing the ultrasonic shear wave and eddy current bolt hole techniques on the samples. Instructions for equipment set-up and calibration were provided in the "Have Cracks" NDI Manual.

SLIDE J-7

The manner in which the inspection of the screening samples was conducted was similar to the "Have Cracks" inspections. Only technicians who were assigned to the "Have Cracks" program participated in the screening program. The technician was given the samples, the inspection procedures, calibration and standards and the reporting sheets and he proceeded as he normally would.

SLIDE J-8

The screening program was first incorporated into the "Have Cracks" program at Tinker AFB and subsequently was conducted at four additional bases. A total of 26 technicians participated. Sixteen inspection tasks were

completed for the eddy current technique and 9.25 tasks were completed for the ultrasonic technique. I might add that 20 of these tasks were performed at two separate depots visited. The remaining six were performed at MAC and TAC bases.

SLIDE J-9

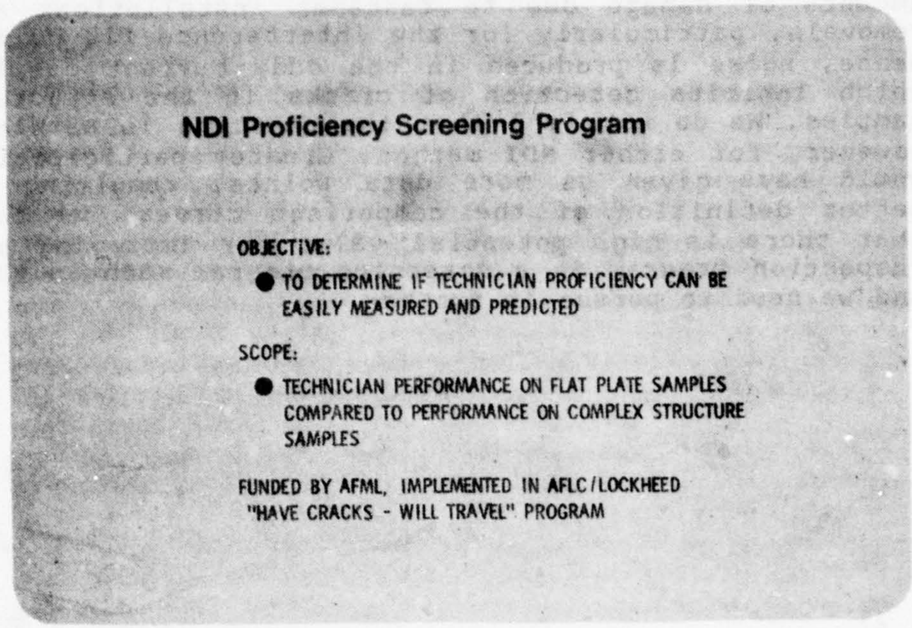
The results were tabulated and were later compared to the results of like inspections on the regular "Have Cracks" samples. Actually, the results of all technicians were combined on a graphic plot in which performance on the screening samples using each NDI technique was plotted against performance on the "Have Cracks" samples. One technician provided one data point on these plots, and is presented in terms of percentage of flaws found. A regression curve of approximately 45° resulted for the ultrasonic inspection - which is just about ideal. This indicates a strong potential for using screening samples to measure technician proficiency in ultrasonic NDI. On the other hand, the technicians using eddy current bolt hole techniques detected essentially 100 percent of the cracks in the screening samples, thus failing to yield a reasonable correspondence between inspections on these samples and structure.

SLIDE J-10

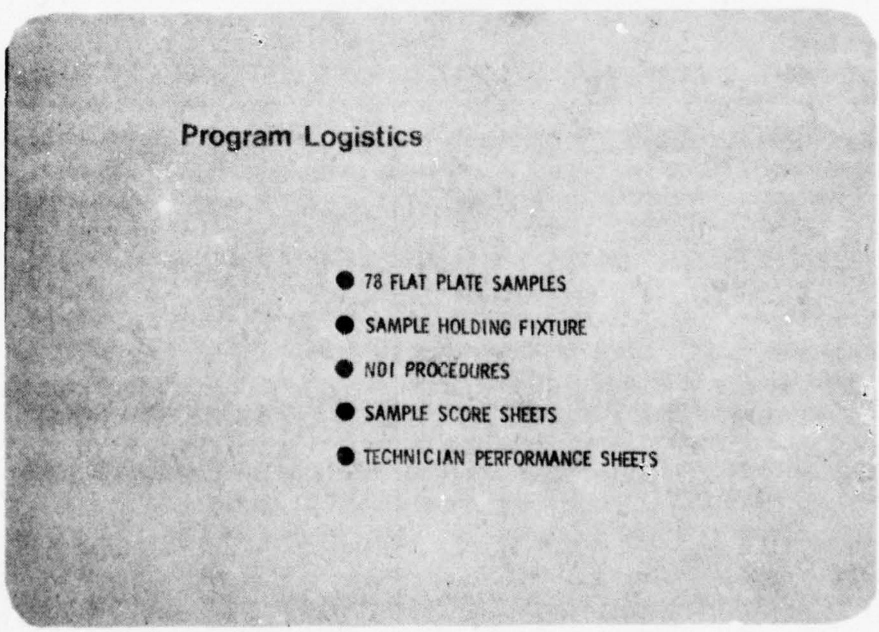
CONCLUSIONS. As can be seen by the plots for the eddy current and ultrasonic techniques, comparing performance on the screening samples to performance on the structure samples, our initial hopes appear to be at least partially fulfilled. That is, we hoped that the experiment would show us that flat plate samples could be used to predict the performance a given technician might be expected to yield during inspection of real structures. This appears to be the case for the ultrasonic technique. On the other hand, the eddy current method yielded an unsatisfactory lack of correspondence, showing that the technicians performed considerably better on the screening samples than on the structure samples. Perhaps there are some good reasons for this. For example, the fastener holes in the screening samples were clean, smooth new holes, whereas the holes in the structure samples contain various

amounts of damage due to fastener installations and removals, particularly for the interference fit holes. Hence, noise is produced in the eddy current display which inhibits detection of cracks in the structure samples. We do not feel that the question is settled, however, for either NDI method. Greater participation would have given us more data points, resulting in better definition of the comparison curves. We feel that there is high potential value for improving our inspection program in a screening program such as this and we need to pursue it further.

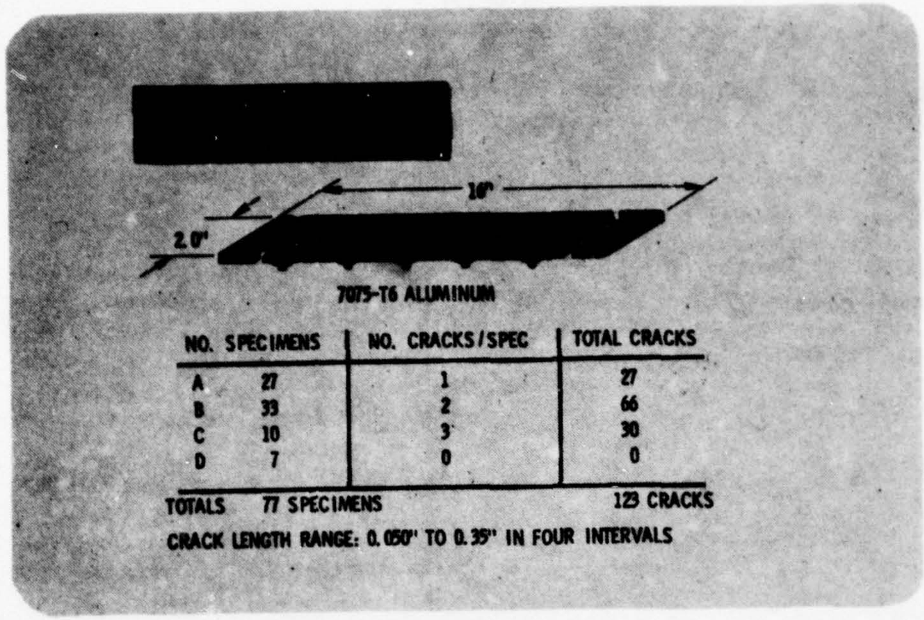
SLIDE J1



SLIDE J2



SLIDE J3



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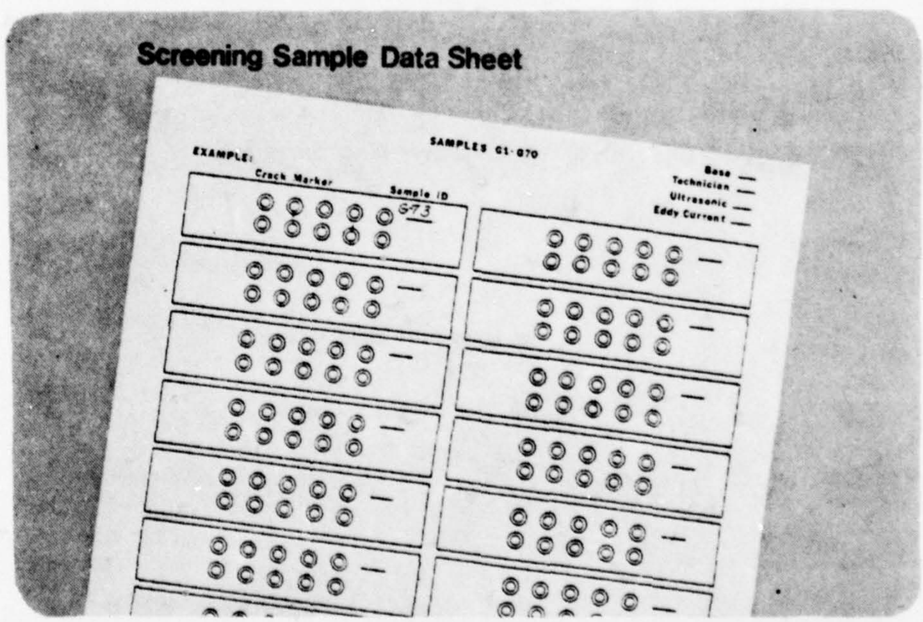
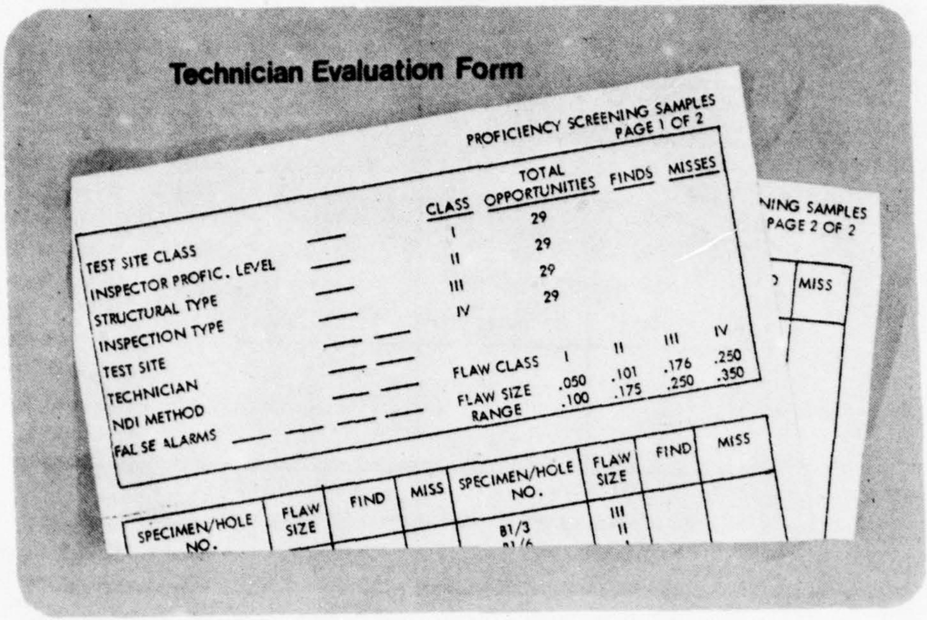
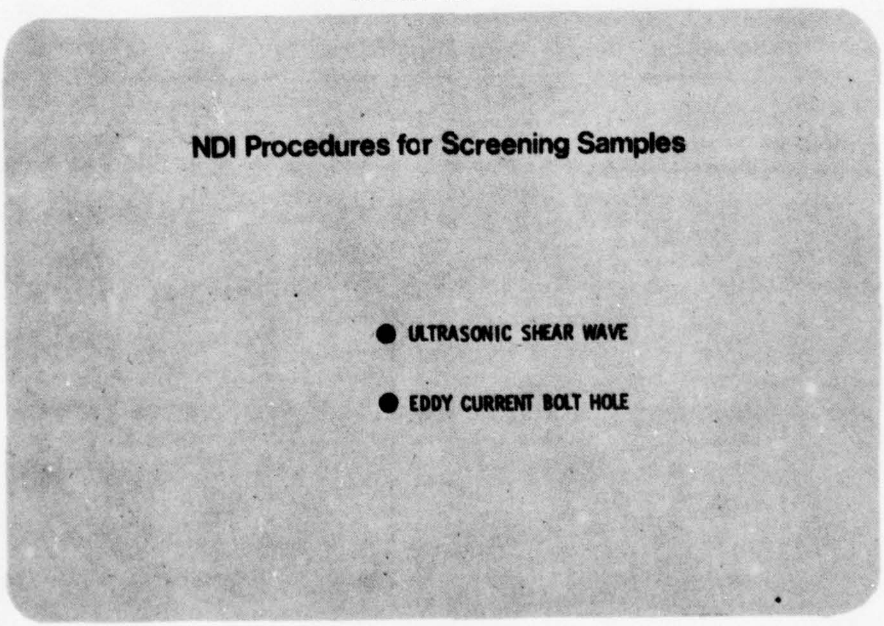


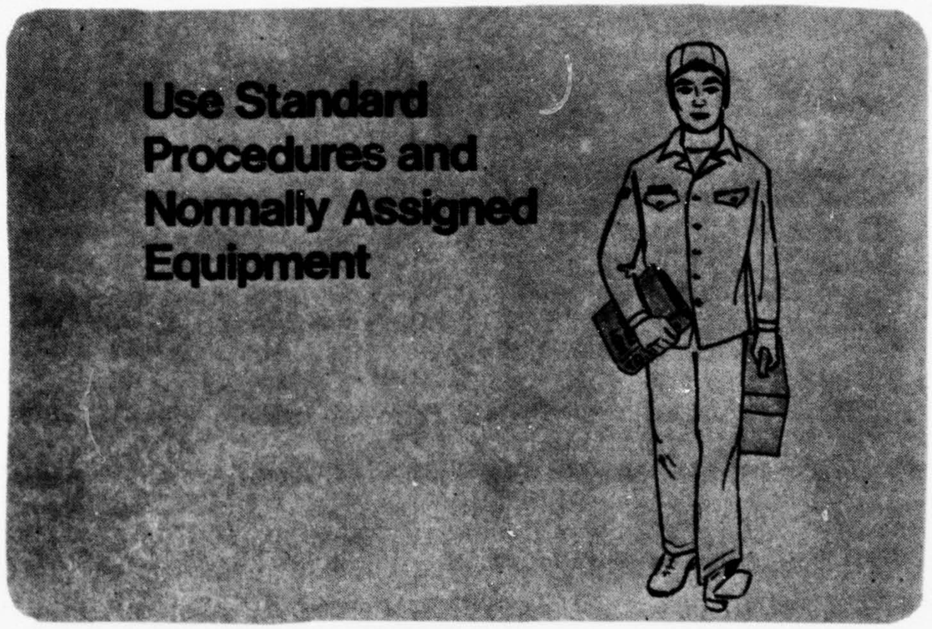
SLIDE J5



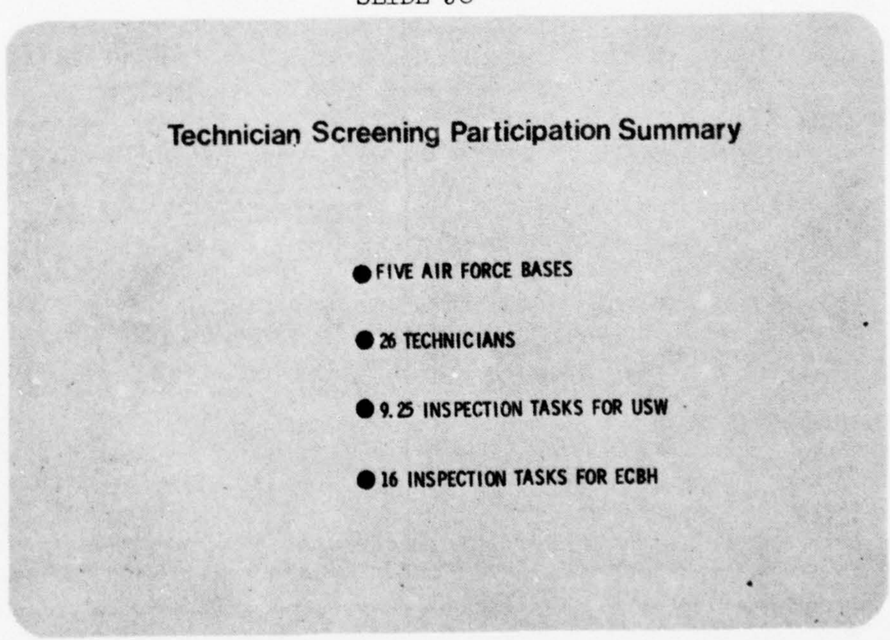
SLIDE J6



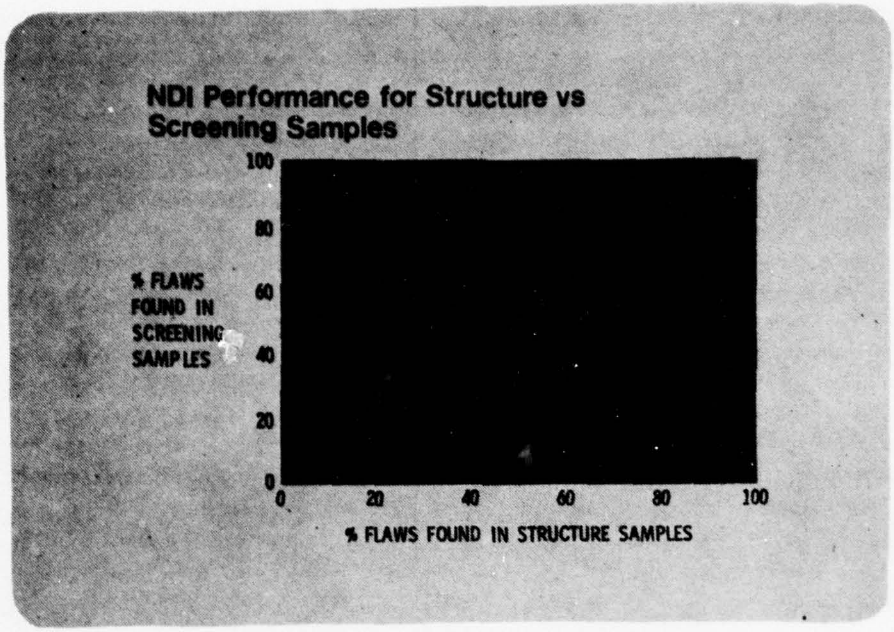
SLIDE J7



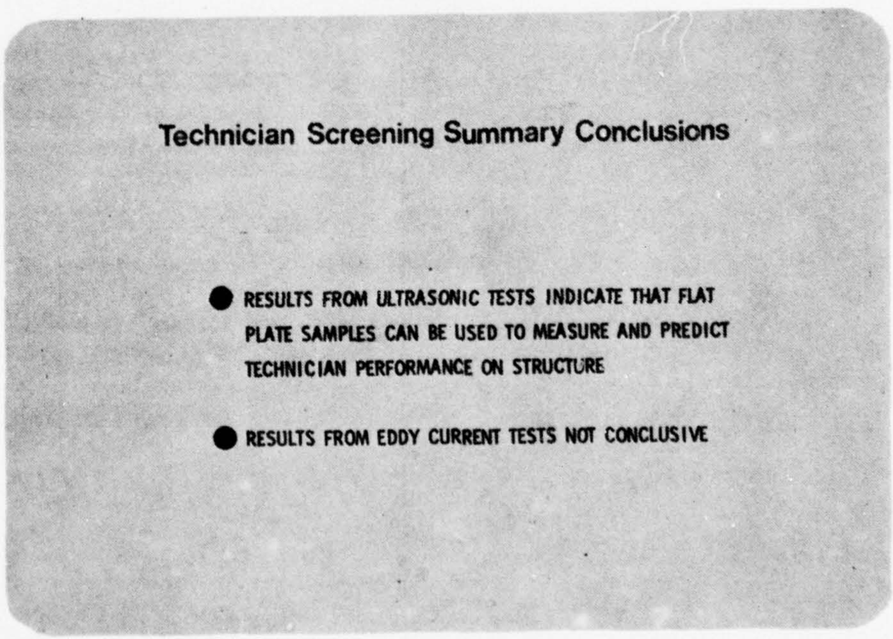
SLIDE J8



SLIDE J9



SLIDE J10



ANALYSIS OF PROGRAM RESULTS

SLIDE K-1

We have noted previously that there are wide variations in the flaw detection probabilities measured for individual inspectors at a given flaw site. Aside from the fact that different flaws may vary - because of their peculiar characteristics - in their susceptibility to detection, we certainly were interested in whether our data could show causes for this variability. Thus, we looked at some factors that should affect proficiency.

We had collected data on personal characteristics and experience of Air Force inspectors which should be directly relatable to their NDI proficiency. We will look at three cases that indicate how NDI performance relates to years of NDI experience, number of hours of formal NDI training and the number of inspections conducted per month for one method. We looked at a composite of results from all participating technicians at the 21 bases and plotted these in terms of the Total Percentage of Finds versus each of the three variables mentioned above, using the data from the eddy current surface scan NDI method. This was done without regard to sample type or flaw size.

The first plot shows the Total Percentage of (Flaw) Finds versus Years (of NDI) Experience. One would expect NDI performance to improve with experience. This plot does not support this premise. Maybe there is a weak trend in that regard. One thing it seems to indicate is that the really capable technicians become good rather early, but many of these may not become career Air Force personnel - leaving the Air Force after 3 or 4 years to apply their skills elsewhere. One other indication is that some of those who do become career personnel either have not sharpened their skills in the eddy current method or are really not suitable individuals for applying it. These thoughts are presumptious and are not to be considered as conclusive. The main thing is to note that there is generally no predictable trend evident from a comparison based on years of NDI experience.

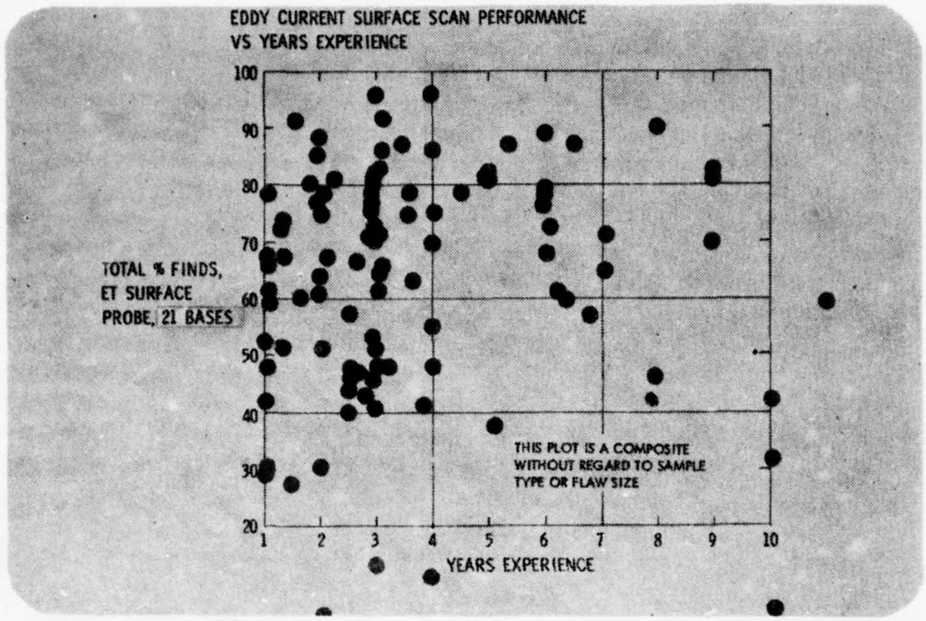
SLIDE K-2

The second plot shows Total Percentage of Finds versus Hours of Formal (NDI) Training. We asked each participating technician to list the number of hours he has spent in formal NDI training. This could include non-military training, but would not include on-job-training. I'm sure there are some inaccuracies in these figures since the technicians entertained numerous concepts of what constitutes formal NDI training. But assuming that the figures are representative of the overall situation, the hours of formal NDI training were examined for its influence on performance. Even though no definite trend is evident, there is some indication that a weak inverse relationship exists, i.e., those with more formal training do not perform as well as those with less. At any rate, the plot clearly indicates that formal training as now conducted and in excess of basic familiarization has questionable value in improvement of the techician's skills. This does not mean that additional training degrades performance, but rather that additional formal training of the types reported does not automatically improve proficiency.

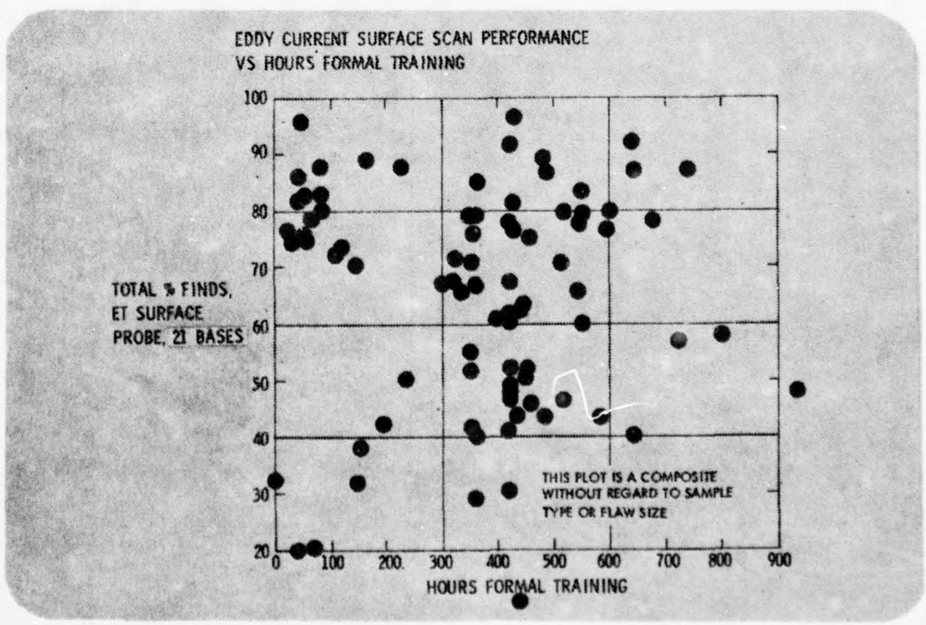
SLIDE K-3

The third plot shows Total Percentage of Finds versus the number of Eddy Current Inspections per month. Again, there is no clear trend evident in the data. There is only a weak indication that performance improves with more intensive practice. However, many technicians are able to perform very well even when they do not have the opportunity to apply the ET method frequently. It should be noted that the eddy current surface scan technique is relatively simple and once the skill is acquired it does not require extensive practice to maintain it. However, poor performance (i.e., less than 40% of finds) seems to disappear when the technician has the opportunity to apply it with moderate frequency (more than ten times per month).

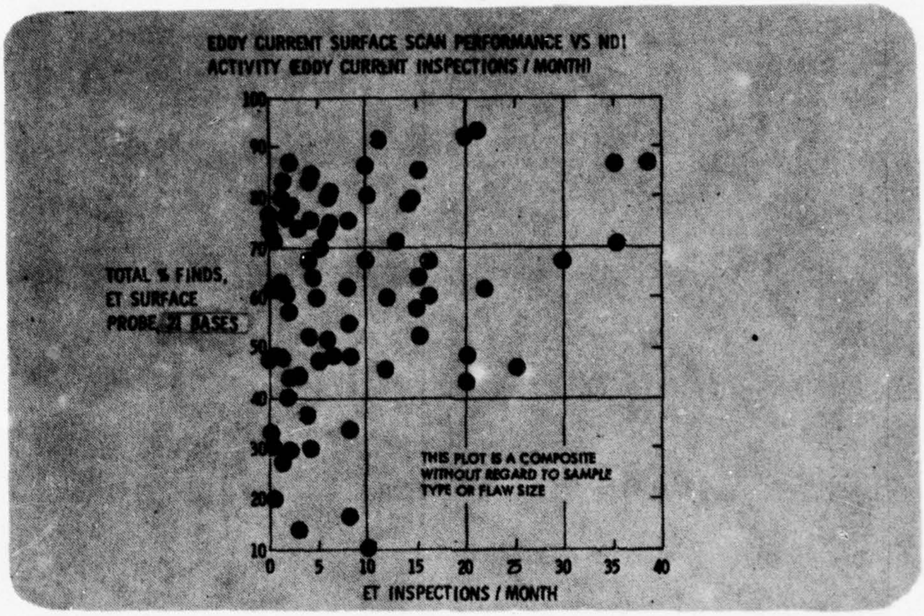
SLIDE K1



SLIDE K2



SLIDE K3


EDDY CURRENT SURFACE SCAN PERFORMANCE VS NDI ACTIVITY (EDDY CURRENT INSPECTIONS / MONTH)
TOTAL % FINDS, ET SURFACE PROBE, 21 BASES
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40
ET INSPECTIONS / MONTH
THIS PLOT IS A COMPOSITE WITHOUT REGARD TO SAMPLE TYPE OR FLAW SIZE

FRACTURE MECHANICS REQUIREMENTS VERSUS EXISTING NDI CAPABILITY

SLIDE L-1

The materials and designs used in modern aircraft do not tolerate large, crack-like flaws. We can no longer wait until a crack is visually obvious, then stop-drill it, and drive on as we once did. Critical, highly stressed components in some of the newer aircraft will not tolerate even a one-half inch long crack before it would be unsafe for further flight. This, of course, is why we now depend heavily on nondestructive inspection to insure the structural integrity of our hardware. But our inspection requirements are becoming more demanding, we are looking for smaller defects, inspecting larger areas, (for example: inspection of 16,000 fastener areas on the C-5 wing), and insisting on greater confidence in our inspection results. In fact, all new aircraft are now being designed to specific damage tolerance criteria with fracture mechanics technology. This technology specifies the precise size of defect which in-service inspections must find and the specific degree of reliability and confidence with which it must be found. Due to the tremendous costs in designing and procuring new aircraft, we now must be concerned with the durability of our present aircraft over extended service lifetimes. As we continue to demand higher and longer performance in our aircraft, our reliance on NDI to insure structural integrity will increase. From this, I think it becomes obvious why we must improve our NDI reliability to increase our confidence that we can find all the harmful defects in both new and aging hardware.

SLIDE L-2

This is a typical example of fracture mechanics technology applied to our present day fleet of aircraft. Shown here is a crack growth curve for a specific location on the C-5A wing where chordwise cracks are predicted to originate from fastener holes in the wing panel spanwise splices. Such a typical configuration is shown in the upper right-hand corner. As you can see from the predicted growth of the crack, we cannot wait

until it reaches a size where we can visually detect it. At such a point in time the crack grows too fast, rapidly becoming unstable and the structure is unsafe for further flight. But the point here is: where can we reliably depend on NDI to detect such cracking? If, for example, as shown by the lower horizontal dotted line, we can reliably expect NDI to detect a crack an eighth of an inch in length in this location, then obviously we should begin our inspections at around 12,000 flight hours and perhaps we might have two or three opportunities during normal major overhauls to detect such a crack before it progresses to the extent where it approaches instability. But how comfortable do we feel with this eighth of inch crack size being reliably detected. As you have seen from the data presented earlier today, an eighth of an inch crack is far below the average crack size normally detected reliably by most routine aircraft NDI inspections.

SLIDE L-3

This is a current inspection requirement on the T38 aircraft currently existing in the Air Force inventory. Here, in a radius area at the wing root, the requirement exists to conduct an eddy current inspection every 100 flying hours for the detection of fatigue cracks. The fracture mechanics analysis showed a requirement for detection of 0.035 inch cracks in this particular area. That is, a crack of 0.035 of an inch in length will grow to its critical size within two inspection periods if left undetected. With this particular inspection requirement, we feel very confident that we can realistically detect 0.035 inch cracks with a high degree of reliability because the area is readily accessible, the cracks are open to the surface and we have both an eddy current and a penetrant inspection method available for use. As you can see the area to be inspected is very isolated and relatively small, less than 2 inches in total length. All of this we feel results in a very direct and highly reliable inspection application. This is considerably different than inspecting hundreds or even thousands of potential crack sites on such aircraft as the KC-135 and C-5 aircraft.

SLIDE L-4

I would like to bring to your attention some of the problems we have encountered in applying NDI reliability data to meet fracture mechanic requirements. One such problem is the obvious gap between the flaw size requiring detection and the flaw size which can be detected with a high degree of reliability and confidence. Another problem exists with the level of crack detection reliability required, that is, 90% probability of detection at a confidence level of 95%.

SLIDE L-6

Let me give you a brief idea of exactly what 90% reliability at a 95% confidence factor actually means. If you were required to demonstrate to me that you could find a one-eighth inch defect at 90 - 95 you would have to find that defect 29 times out of 29 attempts. You would not be able to miss that defect even once in 29 tries. If you did miss it once than you would have to find it 45 times out of 46 attempts, or with two misses and 59 successes in 61 trials, and so forth. The percentages work out to be considerably higher than 90% probability of detection in order to demonstrate that extremely high confidence bound of 95%. The 95% confidence bound is a statistical level of confidence and in reality a 100% confidence level can never be reached as it is an asymptotic limit value. Some people think that a 50% confidence limit means a 50 - 50 chance of success. This obviously isn't so, as can be seen from the lower half of this slide. In order to demonstrate 90% reliability at a 50% confidence level that one-eighth of an inch flaw must be found seven times out of seven attempts. If it is missed once in seven tries then it must be found sixteen times out of seventeen attempts, and so on. As you can see, even a 50% confidence bound is a relatively high level of confidence statistically speaking.

SLIDE L-7

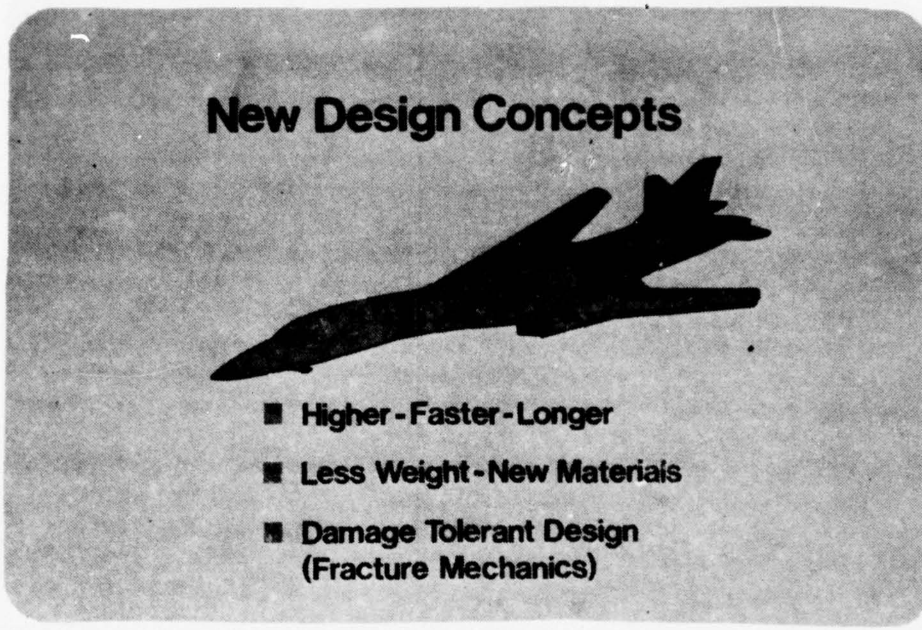
This is another representation of the same information shown in the previous slide and displays the number of successful attempts of crack detection required to

demonstrate 90% reliability at the variously indicated confidence levels of 50%, 70%, 90%, 95% and 99%. When you consider that in a demonstration program not every sample to be inspected will contain a defect requiring detection and, in fact, it is even desirable to have a much larger number of unflawed samples mixed with the flawed samples, then you can see the magnitude in terms of time and expense involved in demonstrating 90 - 95% detection criteria. I don't propose here to offer what is a more realistic confidence level for inspection results to attain; but I am, however, raising the issue of whether 95% confidence is truly a realistic goal in a maintenance inspection environment.

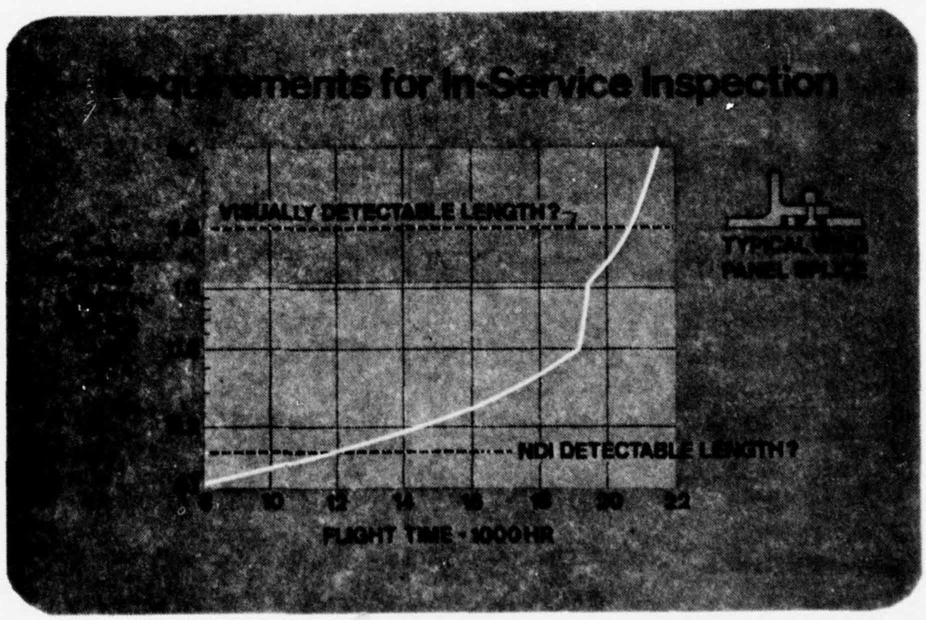
SLIDE L-8

As you can see from this chart, in order to prove or demonstrate a minimum of 90% detection capability at any statistical confidence level, the actual demonstrated detection rate always has to be somewhat higher than 90%. We have to be very careful in applying any confidence levels at all to our inspection results and when we do we must make sure that we know precisely what we are doing.

SLIDE L1

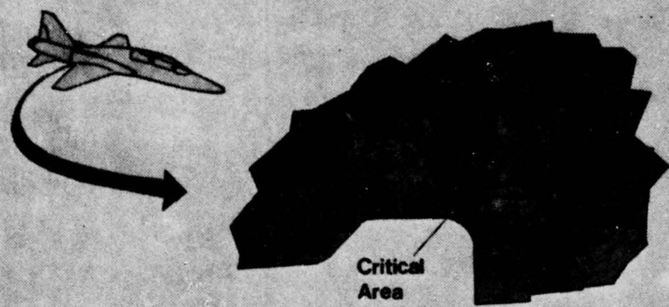


SLIDE L2



SLIDE L3

Typical Existing Inspection



Eddy Current Inspection to Detect
0.035 Inch Crack Every 100 Hours

SLIDE L4

Problem

FM/NDI Interface

- **Allowable vs Detectable Flaw Size**
- **Statistical Level 90-95**

SLIDE L5

NUMBER OF SUCCESSES REQUIRED

FOR 90% RELIABILITY - <u>95%</u> CONFIDENCE

29 SUCCESSES IN 29 TRIALS
45 SUCCESSES IN 46 TRIALS
59 SUCCESSES IN 61 TRIALS
72 SUCCESSES IN 75 TRIALS
85 SUCCESSES IN 89 TRIALS
98 SUCCESSES IN 103 TRIALS

FOR 90% RELIABILITY - <u>50%</u> CONFIDENCE

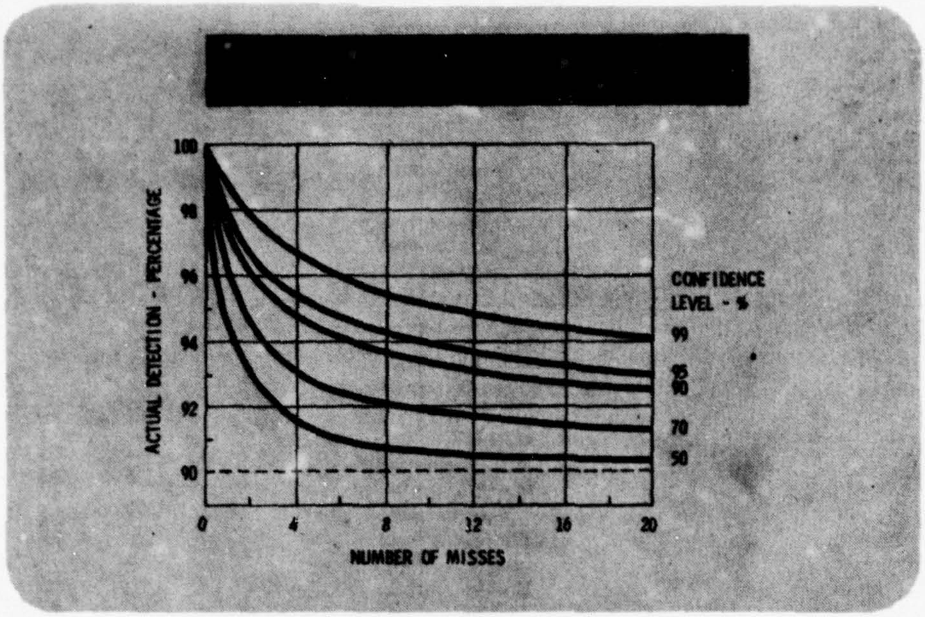
7 SUCCESSES IN 7 TRIALS
16 SUCCESSES IN 17 TRIALS
25 SUCCESSES IN 27 TRIALS
34 SUCCESSES IN 37 TRIALS
43 SUCCESSES IN 47 TRIALS
52 SUCCESSES IN 57 TRIALS
61 SUCCESSES IN 67 TRIALS
70 SUCCESSES IN 77 TRIALS
79 SUCCESSES IN 87 TRIALS
88 SUCCESSES IN 97 TRIALS

SLIDE L6

SAMPLE SIZES AND PERMITTED FAILURES TO DEMONSTRATE A MINIMUM SUCCESS RATE AT 90% RELIABILITY WITH INDICATED CONFIDENCE

NO. FAILURES	CONFIDENCE LEVEL 50	70	90	95	99
0	7	12	22	29	51
1	17	24	38	46	72
2	27	36	52	61	90
3	37	47	65	75	106
4	47	58	78	89	122
5	57	69	91	103	137

SLIDE L7


[redacted]
ACTUAL DETECTION - PERCENTAGE
100
98
96
94
92
90
CONFIDENCE LEVEL - %
99
95
90
70
50
0
4
8
12
16
20
NUMBER OF MISSES

FAMILIARIZATION WITH AVAILABLE COMPUTER

SLIDE N-1

The purpose of this talk is to discuss the data management system and the analysis procedures that were developed for processing the raw inspection data acquired from field and depot bases during the program. These procedures permit a quantitative determination of the significance of various factors affecting Air Force NDI capability. Tthe management system and the procedures are available for use during this workshop and I hope that all of you can take advantage of this capability while you are here.

The effort to develop the data management system and analysis procedures was conducted under a separate program from the NDI reliability program and was funded by AFML. The scope of the effort was to develop computer procedures for the storage, retrieval and analysis of program data. The program involved the design of a data base system, development of pre-processing and post-processing computer programs, implementation of the data management system and an operational checkout of it, an initial data analysis and then a transfer of the operational programs to AFML for further use.

All the significant raw data accumulated from the field and depot bases are stored under specific organized listings in ASD's ITEL AS/5 computer. These data sets are given in both narrative and numerical notation, but are not necessarily identified in the computer as given on this slide. The listings on the slide show the categories of data that are available. They include the structure samples, NDI methods, crack information, base identification, technician's personal and background data, local weather and environment data, inspection dates and results, and listings of technicians in accordance with their relative performance level.

In addition to the raw data listings, there are identifier words by which the operator can recall specific listings for data categories, probability of detection plots for various combinations of parameters which one may desire to analyze.

SLIDE N-2

Use of the data management and analysis system is relatively simple. Raw data in both narrative and numerical form is organized by the system and allows for access by an English-like syntax. This approach allows treatment of data without special programming skills. Output at the remote terminals can be selected for a graphic plot or a printed format. Computer processed information can be output in the form of raw data listings which are selected by identifier words, probability of flaw detection plots also selected by identifier words and variance ratios which are statistically calculated for parameter combinations.

SLIDE N-3

Let me say a few things about the data processing subroutines. The variance ratio calculations allow the operator to determine the significance of changes in flaw detection capabilities. The variance ratios compare changes attributed to some given NDI parameter to influences which can be expected to occur from random data scatter. The calculations will show whether the change is in the scatter band and is therefore insignificant or whether the change is beyond the scatter band, indicating a significant influence of the parameter. The statistical method used will accommodate missing values in the data matrix. In processing variance ratio calculations, we are able to select four parameters at once. For example; what would be the significance on flaw detection probability of using the ultrasonic technique on Fridays at the depots for all program flaw sizes? When the results of this analysis are compared to the same type of analysis determined for Wednesdays, we can evaluate the possibility that Friday may not be as favorable a day as Wednesday for performing ultrasonic inspections at the depots.

We can produce graphic plots of flaw detection probability versus a flaw characteristic, such as length, flaw area or aspect ratio. These plots can be made for selected parameters such as NDI technique, field or depot, structure type, technician experience, and so on.

The graphic plots are statistical representations of the data for flaw detection probability versus selected parameters. Curves are generated for mean values and one-side lower confidence bounds at 95%, 90% and 50% levels of significance. Any parameter in the data list can be selected to examine its apparent relationship to the probability of detection and compared to chance variation with the "F" test for significance.

SLIDE N-4

The post-processing program can be used to investigate interrelationships for selected groups of data to determine their effects on NDI reliability. These examples indicate parameters for which graphic plots of probability of detection versus flaw size can be generated and examined for significance.

The probability of detection versus flaw size can be plotted for each NDI method and each structure type and these plots can be made using the combined results of all technicians or using only the results from technicians in the top 50, 25, 10 or 5 percent performance levels.

Then we can examine the effect that various personal factors characteristic of the technician may have on NDI performance. POD curves can be plotted for parameters selected from the technicians' experience, skill level, education, NDI training and experience, his age, marital status, physical type and so on.

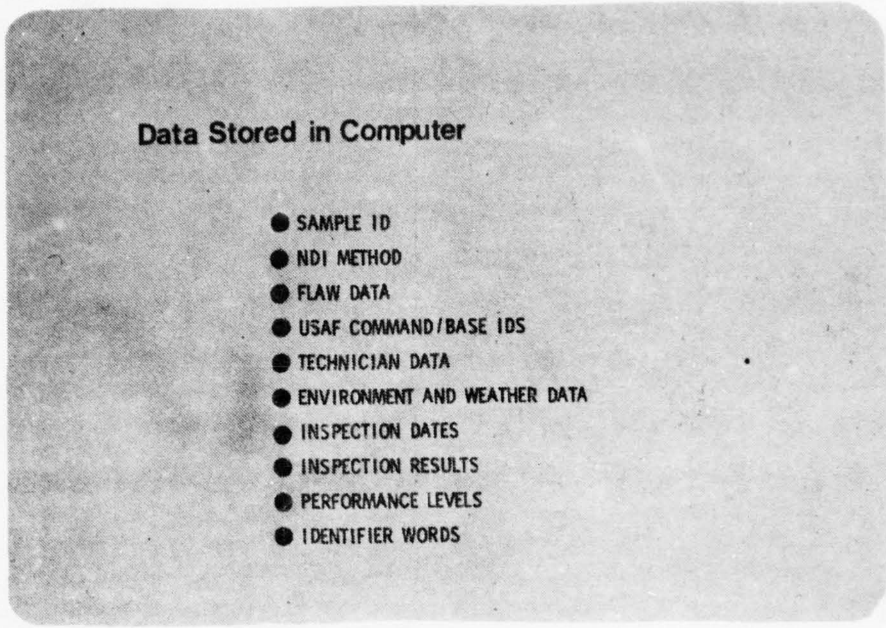
We can make plots for the field base and the depots, then make comparisons for significance between these two types of facilities. We can also look at individual bases and, grouping the bases according to type of command, look at each command. We can compare performance between days of the week, to determine if there is a significant improvement or deterioration in performance for given days of the week. In instances where weather conditions are considered a possible factor, we can determine whether differences are influenced by extreme weather variables.

Now, it is one thing to determine that significant differences exist for some parameters when compared to other parameters; but it is quite another thing to determine the basis for the difference. For example, if we find there are significant differences in performance between two particular commands or between bases within any command, what do we attribute these differences to? Perhaps we can then compare differences in training, overall experience, operational aspects, or some other potential factor to evaluate the reason one base exhibits better performance than an otherwise similar base.

Let me point out that once we have analyzed the data performance levels and significant differences our concern now is with determining the reasons or causes for good or bad performance and the differences between performance levels. Only by finding these basic causes can we devise effective and efficient efforts to improve the NDI capability. Certainly, we would like for the capability to be as high as reasonably possible and we would like for the performance level to be uniformly high across all Air Force bases and Commands. Our question is "What things must we do to bring this about?" What changes must we make in technician selection, formal NDI training, job assignment, on-job-training, and so on, to make worthwhile and permanent improvements?

Our computerization of data, storage, retrieval and processing has been designed to allow us to make statistical analyses for a broad range of conditions. These analyses will tell us what the average performance is for the selected set of conditions and can tell us where significant variations exist. But it is our insight and ingenuity that will allow proper use to be made of the analyses to find the causes, make correctional changes, and thereby achieve the true objectives of this effort.

SLIDE N1



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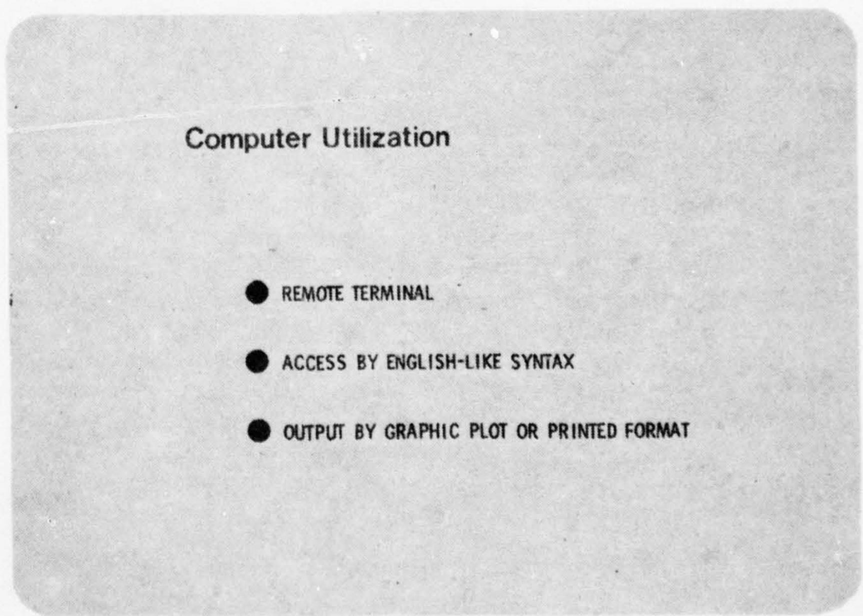

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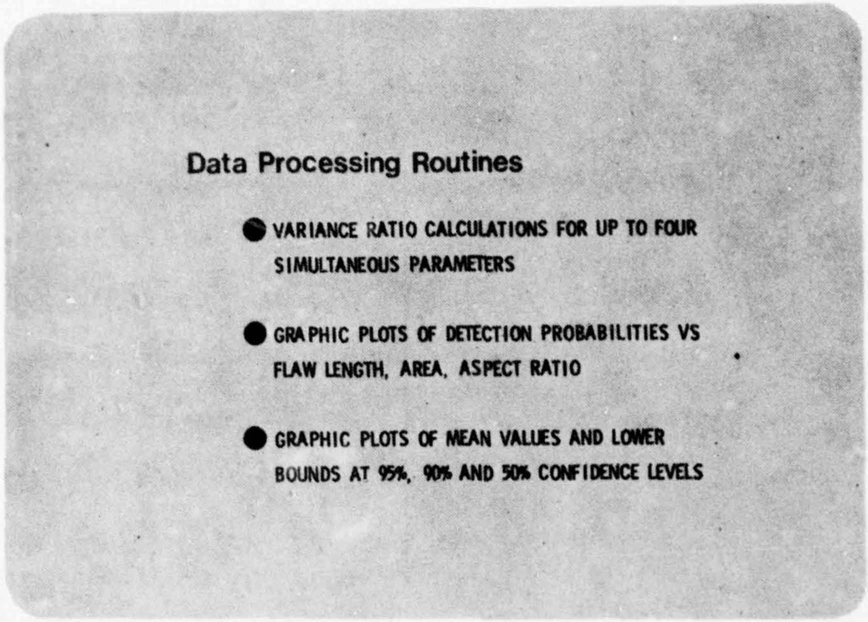

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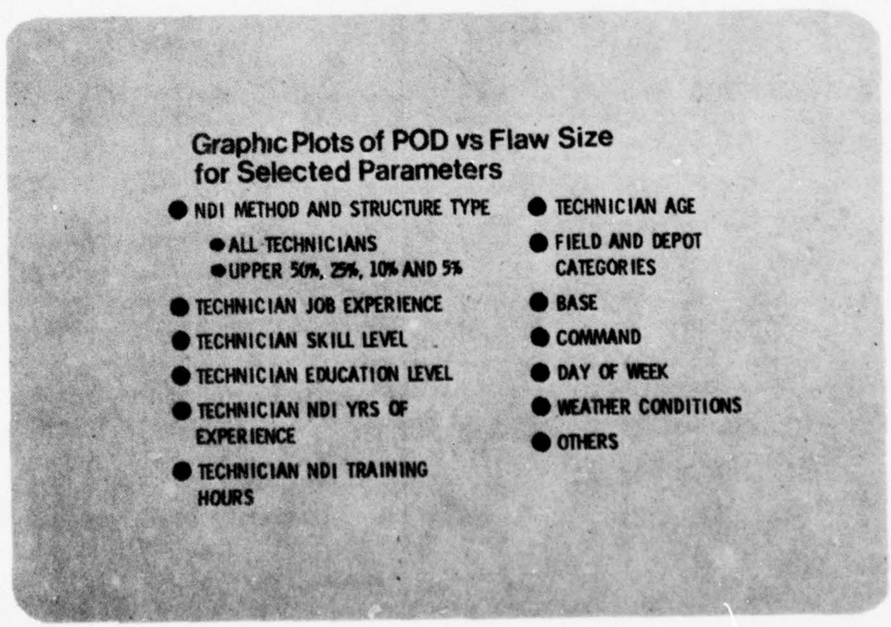


Section IV
WORKSHOP TASK GROUPS

Task Group Function

The heart of the Workshop was the Task Groups composed of the attendees. The Task Groups were established to address specific aspects of NDI which were of general interest to both industry and the Air Force. The object of these groups was to consider the results of recent programs designed to measure and evaluate the reliability of NDI and to determine what can be done to improve NDI effectiveness. Leaders for each of the Task Groups were preselected from the preregistered attendees by the Workshop organizers based on their particular background and interest in the specific area concerned.

Preparation and distribution of Task Group Packages was accomplished to initiate in-depth studies of the USAF/Lockheed NDI Reliability Program. Additionally, quantitative results to questions and problem areas were provided by computer access to the Reliability Program data bank through a remote terminal located in the Workshop. Curve plotting and data printouts specified by selected variables were made available on request from data processing subroutines in the computer. The Workshop goal was to formulate concensus recommendations to further the improvement of NDI and to suggest programs which would provide a more quantitative evaluation of NDI and to implement improvements in maintenance inspection operations. A detailed explanation of each of the eight areas covered by the Task Groups is given in the following section.

Task Group Breakdown

Task Group I - Personnel

This task group was concerned with the problems and methods of improving the initial selection of inspection personnel and the maintenance of high levels of capability of existing personnel. Basic concerns included discussions of personnel background and characteristics which may be indicators of good NDI

technicians. The task group considered these possibilities as well as questions such as how may NDI personnel be motivated to always do their best; what incentives would induce technicians to improve their capabilities, and what human factors affect NDI operations and how can they be controlled? Task group participants were given the opportunity to discuss and answer these questions based on their past experience and expertise.

Task Group II - Training

This task group explored both formal and on-the-job training of NDI personnel, emphasizing the factors that would produce better qualified personnel and promote reliable inspections. The quality, content and emphasis on initial and continuing formal training and on-the-job training was addressed. Other items discussed included: Methods to obtain an optimum balance between NDI theory and practice in the training of both laboratory and field personnel; should specialized or generalized training be pursued?; methods for measurement of NDI training effectiveness; evaluate means to minimize cost of NDI training; determine how much practical training is necessary.

Task Group III - Operations

This task group addressed NDI operational factors that can lead to improved NDI reliability. Topics of discussion involved the optimization of the NDI task size, job scheduling at the most favorable time of day or week, desirability of working technicians in pairs and definition of key environmental factors for greater efficiency. Other areas explored included the recognition of NDI as a discipline within the organizational structure; the relationship of the depot to field units in terms of schedule time for each NDI task, in supply of standards and equipment and in the validation of techniques or T.O.'s for field use. This task group also addressed the problem of personnel training, whether personnel were assigned primary or secondary duty as NDI technician and the need for qualification in all methods of NDI.

TRAINING TASK GROUP IN SESSION

CERTIFICATION TASK GROUP IN SESSION

Task Group IV - Certification

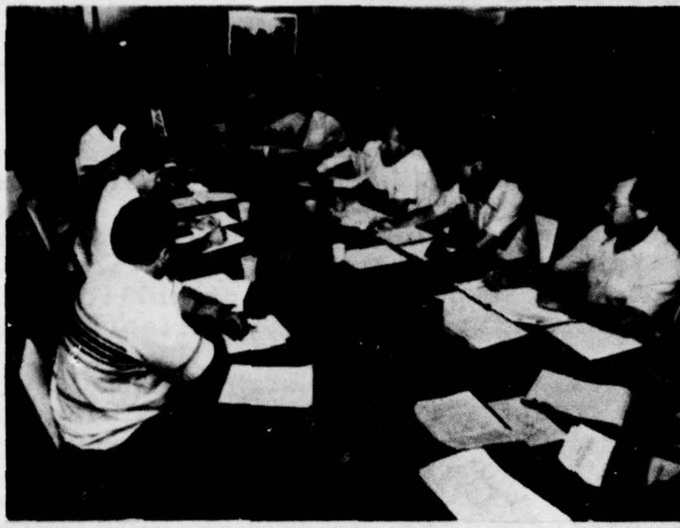
This task group was concerned with the certification and qualification of NDI personnel. Questions considered by this group included: Would certification improve NDI reliability?; should laboratory as well as field or shop NDI personnel be certified and how should qualification be attained and how measured? How often should certification be required and who should conduct the verification functions? Since certification demonstrates knowledge of the principles and practices of NDI, should the technician also be required to demonstrate his skill in performing practical NDI?

Task Group V - Equipment

This task group was concerned with potential improvements in NDI equipment designs for greater compatibility with human factors in search, control and display. Other considerations included the reduction of operator dependence in flaw detection systems, permanently recording inspection data for improved detection and interpretation, equipment design considerations for defect search and characterization modes, design and availability of inspection standards, and the effect of equipment performance on total NDI reliability. Is it practical to design equipment for compatibility with human capabilities rather than trying to adapt humans to fixed equipment designs?

Task Group VI - Reliability Measurement/Modeling

This task group explored the possibility of translating the data and results from the "Have Cracks" Program and similar efforts to other NDI applications. Could a model be developed to predict the relaibility of a specific nondestructive inspection? Determine approaches to modeling which would improve measurement programs such as "Have Cracks" Program or extend it to broader representative structure. Based on data obtained in "Have Cracks" Program, could a simple NDI test such as the screening samples be developed to effectively replace more extensive evaluation programs? Should the inspectors know they are participating in an evaluation program? Define parameters considered



EQUIPMENT TASK GROUP IN SESSION

RELIABILITY MEASUREMENT/MODELING TASK GRP. IN SESSION

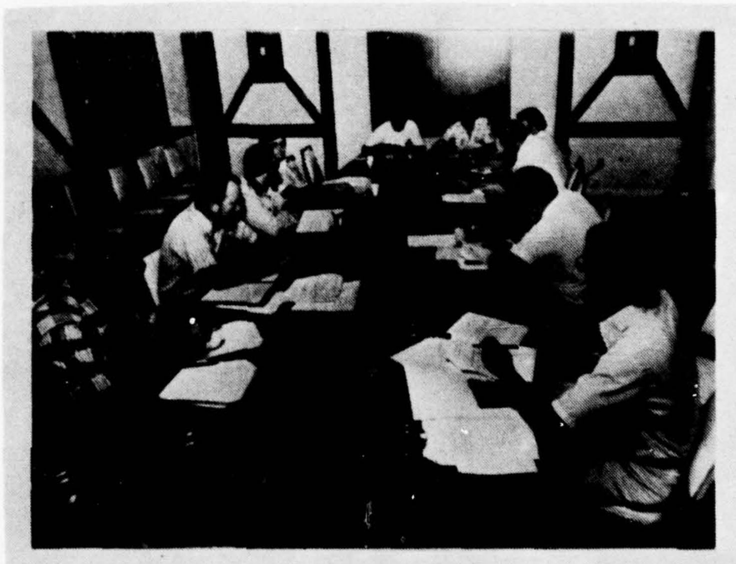
essential to an objective modeling approach to NDI reliability measurement.

Task Group VII - Fracture Mechanics/NDI Interrelationship

This task group reviewed the relationship and use of NDI reliability data in structural design based on fracture mechanics design principles. Discussions involved the interrelationship of fracture mechanics and NDI with regard to transfer of informmation and communication, the limitations and capabilities of each discipline, and the effect of the reliability program on structural design philosophy. The existing NDI reliability data were studied with regard to current FM/NDI design practices which assume a minimum detectable flaw size. The need for 95% confidence level on NDI reliability was reviewed and the requirements for both confidence level and detection of minimum flaw size were assessed for realistic application in aircraft safety. Further discussions involved the necessity for timely dialogue/communication between NDI, fracture mechanics and design organizations to ensure compatibility between requiremens and practical capability.

Task Group VIII - Data Analysis

This task group was concerned with the analysis, interrelationships, presentation and application of existing NDI reliability data. This included problems such as dealing with false calls, the construction and use of detection probability curves, analyses of variance or co-variance and determination of confidence limits, and how to most effectively format data relationships. Discussions also centered on the best way to determine the significance of variations in NDI reliability data using the co-variance technique and alternate methods. Parametric studies were discussed relative to presenting NDI reliability program results in various formats compatible with the desired use of the data.



FRACTURE MECHANICS/NDT TASK GROUP IN SESSION

Section V
TRANSCRIPTION OF TASK GROUP REPORTS

Business Meeting, Government/Industry Workshop on NDI Reliability, held at the Shamrock Hilton Hotel, Houston, Texas, on August 4, 1978, beginning at 8:30 a.m., reported in shorthand by Kathleen Alford, Registered Professional Reporter, Notary Public, Harris County, Texas.

I. PERSONNEL

TASK GROUP LEADERS:

R. L. Wolford
S. I. Shelton
Bob Erwin

R. L. Wolford, Summary for the Personnel Group: The task for which Sam Shelton and Bob Erwin and I were assigned was identified as Personnel. The charter for that group was to determine what type of an individual might best become a satisfactory NDI technician. We had some very interesting discussions, which I am sure all of the groups must have had. There was considerable amount of interest, considerable amount of varied discussions on what the individual should have. Everything from motivation -- and there were those who thought that the only motivation was money. There were those who had the feeling that there were a lot of other things much more deeply of concern than money -- that money became a secondary thing if you were successful in the other items, the money would be there. We were fortunate in having in the group representatives from the Canadian Air Forces, Royal Air Force, as well as our own Navy and Air Force personnel. We were able to make comparisons between the methods utilized in those military services in the selection of personnel for NDI work. We had, of course, representation from industry. There is a vast latitude of difference between all of those organizations that I mentioned. We

have put together a couple of viewgraphs. This viewgraph identifies in an abbreviated form what we believe our charter was: To determine the methods required to improve the initial selection of NDI personnel and the maintenance of high levels of capability of existing personnel. How can NDI personnel be motivated to do their best?

That briefly was what we believed our charter to be. The next viewgraph -- these were the major items that seemed to predominate our group. Develop a human factors profile which identifies basic requirements. The individual is to have integrity, a sense of responsibility, he is to be mature enough to recognize his responsibilities, a pride in accomplishments. He had to be a person who was self-motivated, self-disciplined, who could discipline himself to work in the various environments. He had to be an achiever. He had to have moral convictions. He had to have allegiance and decision-making ability.

Admittedly, those are some very difficult requirements to find in a single individual. But these are the things in summary we found the individual profile would require. Integrity, he had to be able to understand his responsibility and to be moved to follow those convictions and to make the decision that is necessary. I think basically that most of those are understood by all of us and recognized for their individual responsibilities in a person performing this kind of a task.

Then there are certain technical requirements that the individual should have. He should have the ability to use the tools of the profession. He should be able to demonstrate a proficiency in the basic sciences. He should have training or work experience in the type material or structure to be worked with prior to entering the NDI field. This says that there should be a training period in which the individual gets extensive -- and I am not going to attempt to identify what extensive might really be at this point. He should have enough experience that he feels free in the use of the equipment. He understands the equipment. He understands the purpose that the particular equipment and technologies have and what their limitations are. He

PERSONNEL

DETERMINE METHODS REQUIRED TO IMPROVE THE INITIAL SELECTION OF NDI PERSONNEL AND THE MAINTENANCE OF HIGH LEVELS OF CAPABILITY OF EXISTING PERSONNEL. HOW CAN NDI PERSONNEL BE MOTIVATED TO DO THEIR BEST?

VIEWGRAPH 1

DEVELOP A HUMAN FACTORS PROFILE WHICH IDENTIFIES BASIC REQUIREMENTS, i.e.

- INTEGRITY
- RESPONSIBILITY
- MATURITY
- PRIDE IN ACCOMPLISHMENTS
- SELF MOTIVATED
- SELF DISCIPLINED
- ACHIEVER
- MORAL CONVICTIONS
- ALLEGIANCE
- DECISION MAKING ABILITY

VIEWGRAPH 2

PERSONNEL

- ABILITY TO USE TOOLS OF THE PROFESSION
- DEMONSTRATE PROFICIENCY IN THE BASIC SCIENCES
- HAVE TRAINING OR WORK EXPERIENCE IN THE TYPE MATERIAL OR STRUCTURE TO BE WORKED WITH PRIOR TO ENTERING NDI FIELD.

VIEWGRAPH 3

RECOMMENDATIONS

- DEVELOP A METHOD FOR EVALUATING NDI PERSONNEL RE THE PROFILE
- INITIATE PERSONNEL MOTIVATION CRITERIA WHICH WILL PROMOTE PERFORMANCE EXCELLENCE
- DEVELOP RECOGNITION FOR OUTSTANDING ACCOMPLISHMENTS
  - COMMENDATIONS
  - ADVANCEMENT POTENTIAL
  - MANAGEMENT ACKNOWLEDGEMENT
- DEVELOP FEEDBACK SYSTEM

VIEWGRAPH 4

should be able to demonstrate those proficiencies and all of the disciplines and with all of the types of equiment that he is going to be expected to work with and the type of structures that he is going to work on -- if he is going to work in finished products such as an aircraft and that type of thing. Going to the last item, he should also understand something about aircraft structures. There should be some education in that area. Make him realize the importance of his inspections. Where critical structure areas are that he has a high degree of responsibility in the decision that he makes; he should be made to understand that he has a responsibility, a real responsibility for that decision. If he is going to work outside, if he is going to work in a plant on more of a production line NDI job where he is doing penetrant or mag inspection as opposed to maybe doing ultra-sonic, eddy current, or radiography. He is looking at individual parts. There is a difference between that type of inspection and one out on the line in which you are working in the environment that are quite different from those in shop environment.

It makes no difference if he is going to work on pipelines or building construction or whatever. He should have a good knowledge of the types of structures and material that he is working with and how his equipment is going to perform with those materials in those types of environments.

Recommendations:

To Develop a Method for Evaluating NDI Personnel; Re: The Profile. The things that we showed you, a means of identifying how many of the things we put in the profile that that individual has. And, if necessary, those could be put in a priority, which ones of them you thought were the most important and where you wanted to place your most severe measurement of the individual.

Initiate personnel motivation criteria which will promote performance excellence.

Develop recognition for outstanding accomplishments. Some of the suggestions that came out of the three

different sessions were commendations of some type, advancement potential. He should understand what his potentials are. How far can I go in this business? Management acknowledgement, I think most all of us enjoy occasionally to be recognized for having accomplished something that is over and beyond the normal call of your job duty. Somebody at least was aware that you did a good job. You did it ahead of time. You saved some parts that might have been scrapped if less than more critical review of your inspection had been made.

Develop a feedback system. One of the things that was brought out was that maybe it would be interesting if we took those suggested questions that were in your packet which were really there to help motivate your discussions in your respective task groups, if you took those same questions and went out to your NDI personnel, whether in your plant or out on an air base, a station, or whatever, and had your people look at those eight tasks and the kind of questions that were there and see what they thought their job task was, what they found and would suggest to you as being desirable factors that would help them to do a better job, where they felt that maybe they were short changed in their training program, lack of proper maintenance of their equipment. These are some suggestions that we would identify with these recommendations.

This is a capsulated presentation of the three sessions and a very brief summary of what we felt were the major items to come out of that particular task.

UNIDENTIFIED SPEAKER:

I would like to know what data you used to come up with these items, or is it a collection of personal opinions?

MR. WOLFORD:

These were out of the three groups. We started out with the first question in the first task group, personnel. We found that all of the other questions that they had there became redundant to that which was asked in the first question. These were the things that either were

agreed upon by the groups or that they were predominant in the suggestions that were made by the representatives in those three sessions.

UNIDENTIFIED SPEAKER:

Was any attempt made by any of the groups to prioritize even in the way of grouping these various factors that have been identified as being desirable?

MR. WOLFORD:

The question was: Was there any attempt to prioritize the suggestions that were established here, whether they be I suppose you mean in the profile.

UNIDENTIFIED SPEAKER:

Yes, that list of desirables. Which are the most important?

MR. WOLFORD:

I don't think that I can at this time, Tom, say that there was as a summary of the group to have prioritized. I would say that these are items that came out that were predominant in the discussions. And I think a review of these items with a group of people that are really concerned about this, to study this may be in a human factors type thing to determine which of these has the greatest bearing on maybe another one,a subsequent one and so on. But we did not have any priority establshed.

The question was: Where there were general statements made on the view graphs, would there be more specific things such as assuring that the individual knew how to read blueprints.

Yes, because we were not sure how many viewgraphs or how far to go in trying to break down at this particular time all of the things that you can believe were akin to this. When we said to be familiar with the structures, certainly we felt that -- and I say the three of us that were task leaders in summarizing this,

and I suppose with some degree of personal opinion also, these questions came up. You introduce your own personal feelings also -- that the individuals had to know how to read blueprints. They had to understand part of this was training and understanding structure and the meaning of stucture, the importance of one part of a structure for instance in an airframe over another part of it.

What is fracture critical, for example, as opposed to a maintenance critical and so on down the line.

The individual's question was that there needed to be some definition of the latitude, I would say, of what the individual could deviate from the technique in his inspection.

Now, this was part of the discussion. How far do you go? Does the individual have the responsibility to make a final decision? Work techniques, was he working from techniques such as -36 or other specific techniques developed? Should the individual have any prerogatives in deviating?

There is, I would say, a wide latitude in some areas whether the individual should have those prerogatives, that there is a continuity between one inspector and another inspector on a day-to-day basis, whether they have how much prerogative to deviate, or whether you give them specific guidelines for a particular structure to assure that there is a continuity in the inspection.

Are there any other questions?

UNIDENTIFIED SPEAKER:

I see nothing here in terms of physical characteristics of personnel. Was that not considered, or was it considered adequately covered already?

MR. WOLFORD:

These were discussed briefly as being part of the requirement. They were not identified here because of

the restriction of time and space on viewgraphs. But, yes, this would be part of the requirement. There would be certain physical requirements that the individual would have to have. There are certain tasks where a person with certain types of handicaps would function very well. Physical, lost arms and legs, etc., some cases have to sit down depending upon what kind of environment the individual is working in. Certainly working out on a flight line, there would be some restrictions and some limits to be placed as opposed to working in a plant where a person could sit at a bench maybe and do certain types of ultrasonic, conductivity, mag particle inspection and things of that nature. But we did not get into any detail about physical requirements specifically.

UNIDENTIFIED SPEAKER:

In the area of technical requirements, training and work experience, related fields, related materials, prior to entering the NDI field, I think it is a very important point. I was wondering what specific experience was discussed and deemed to be important to move into the NDI as a machinist, mechanic, a maintenance man on the line. What really contributes to good experience and background of this?

MR. WOLFORD:

The question was: In the technical experience prior to going into the NDI field was there any discussion as to whether he should have machinist experience, to be a mechanic, and so on.

Yes, there was. In fact, in our discussions with representation from the RAF and the Canadian Air Force in particular we spent quite a bit of time in the session in which they were representatives reviewing the techniques used for qualification there. And for the benefit of those of you who may not have had the opportunity to get that kind of information, they have a requirement that the individual has to have been in the service and been either in aircraft structures or an engine mechanic for six or seven to nine or ten years. Then he can apply for NDI. He then goes through

an interview, an oral interview, which is conducted by an individual but that individual also pulls in certain individuals with on-the-line current capability in the NDI field who also interrogate the individual. If he passes that interview, he is then put on a list, a wait list. And when the opportunity opens up for another slot, he then is sent to school. He attends school for a prescribed period of time with a prescribed study in all of the disciplines. He may be weeded out in that school period. After he graduates from the school, he then has a six-month work period working with other NDI people. He has no authority to sign off on jobs during that six-month period. And working with his peers during that period he may get washed out at that time. If he demonstrates certain qualities that are felt not to be desirable, he could be washed out. After the six-month period if he has passed all of that, he then has the authority, and there they have the total authority. They can ground an airplane. And it takes a considerable amount of doing to change his decision. This places a tremendous amount of responsibility on the individual, and he recognizes when he goes into the program the extent of that responsibility. It is developed to be a prestige, a highly desirable organization to be a part of. There is a considerable amount of pride in having achieved the opportunity to become an NDI technician engineer type.

We understand that very few that achieve that level ever leave of their own volition or are forced to leave because of poor conduct in carrying out their tasks.

This is, in a brief discussion, one of the things that was discussed at length relative to one type of method for evaluating.

UNIDENTIFIED SPEAKER:

I would like to comment on that. One of the dumps we had done yesterday will cite a sample. We looked at folks who had high time experience prior to going into the NDT field, and those folks were consistently among the poor performers. I am talking something 10 years or

more prior to going into the NDT field. So that with respect to our sample group this evidently did not hold true.

MR. WOLFORD:

The question was that in their discussion group yesterday they reviewed computer printouts that showed that people with high time experience prior to going into the NDI field did not necessarily perform in the NDI field in the top capability.

We saw some of those printouts. We also noted that depending on one discipline, eddy current versus radiography, that it was pretty random. I don't know that we could really say that we saw that there was consistently poor showing on those that had other skills prior to going into the NDI field.

But I am only relating to you what has apparently been very successful in the RAF and in the Canadian Air Forces.

Are there any other questions.

MR. BOISVERT:

II. TRAINING

TASK GROUP LEADERS:

John Dorgan
C. J. Hellier
V. L. Stokes

JOHN DORGAN, Summary on Task Group Training: We had about 26 people to participate in the three sessions that we had. It was a pretty good cross section between Air Force, Army, Navy, salesmen. We had some gentlemen from Australia. We had some from England. So, it was a pretty good cross section.

It is pretty hard to stand up here and relate what 26 people were trying to communicate. But the first thing that we wanted to do was try to find out just who did we want to train, what type of individual. And this more or less overlaps into the preceeding presentation of personnel.

If you cannot read them, they are:

Integrity
Desire to be in NDI

That means he has to volumteer. We are not going out to solicit people to be in NDI. They have to want to be in the field in order to work in it.

Above average. What this means is his past history, his past experience in companies or in military, or whatever the case may be, he had to be an above-average type performer, this sort of thing.

Product awareness. That means to have prior experience with the product that he is to inspect, whatever it may be, structure, engines, commercial product, whatever.

Vested interest in company or agency. What we interpret this to mean is he had to be with the company or the organization for some period where he had some time invested in regard to his retirement, job security, senioroity, items such as this.

And adaptability. This means that he would have to be able to physically, mentally, and so forth to accept the responsibilities of the areas that he was expected to work in such as cold, hot, flight line, in-shop, these sort of things.

So, this was the type person that we had determined that we really wanted to train and really wanted into the field. In all three sessions we had a considerable amount of discussion about not so much as to the time dedicated to the training, although we did use a base of like 80 hours one time for radiography, but the amount of time with classroom formal-type training --- this is in a lecture-type environment versus a practical hands-on-type thing where you are actually using the equipment with an inspector or another person of higher knowledge looking over your shoulder to give you instructions in the particular inspection medias.

You can see the first phase. The first phase which we considered in the military, or like the Air Force, would be considered the three level. And in industry it would be the level one certification. That was classroom, 45 percent, and the practical hands-on, 55 percent.

Now, there was a little bit of confusion between some of the participants in that, for instance, reading radiographs, was that considered hands-on or was it considered formal classroom training. So, there was somewhat of a split opinion there as to which one it correlated to.

In phase two, which we considered in the air Force as being five-level training but in the industry, level two training, that correlated to 35 percent in the classroom environment and 65 percent for hands-on training. There was a lot of discussion leading up to these percentages, that being: Where do you want the most of the emphasis, out there where he is actually working on the equipment, where you make your money, where you had the reliability in him, if he happened to miss a discontinuity or miss a defect that you want him to look at, if you want him to be a part of the equipment so that he wouldn't really understand thermionic

TRAINING

PREREQUISITES FOR NDI TRAINEE

INTEGRITY

DESIRE TO BE IN NDI

ABOVE AVERAGE

PRODUCT AWARENESS

VESTED INTEREST IN COMPANY OR AGENCY

ADAPTABILITY

VIEWGRAPH 1

(1) ALLOCATION OF TRAINING TIME

	CLASSROOM (THEORY)	PRACTICAL (HANDS-ON)
1ST PHASE	44%	55%
2ND PHASE	35%	65%

(2) HOW IS EFFECTIVITY OF TRAINING MEASURED?

a. PERFORMANCE ON THE JOB

b. EXAMINATIONS

c. EVALUATION BY SUPERVISION

(3) SHOULD NDI PERSONNEL HAVE SINGLE OR MULTIPLE CAPABILITIES?

IN GENERAL, MULTIPLE ___

VIEWGRAPH 2

emission but just know how to operate the equipment itself versus a deep theory and understanding of what is actually going on inside the material.

The next item that we went to is: How is effectivity of training measured? There were three items that we came up with, one being the peformance on the job. That is that when an individual first comes into your function or your organization what you do is that you inspect after he has inspected an item. That means that he inspects something and then you go out right after him and see what he has told you is correct until you have built some kind of confidence in him.

Examinations. This was written theory as well as practical examination, somewhat similar to the "Have Cracks will Travel Program."

Evaluation by supervision. A lot of this whole program in training and in what is expected of the individual lies right on the integrity and the enthusiasm, spirit of the supervisor himself. You know yourself that whatever your supervisor expects of you that you are going to try to rise to his expectations. So, the whole program, regardless of what it reads on paper and regardless of what it tells us to do, lies right in the hands of the supervisor -- how he produces or controls his own program.

Should personnel have single or multiple *discipline* capabilities? Now this again is according to circumstance or in an area in which the person is expected to function. In an industry-type mass production-type thing we concluded that it would be sort of silly for a manufacturer or an organization to train somebody in all the functions of NDI if all he is expected to do for instance is sit on an assembly line and read items going through a penetrant-type inspection. This would be considered quite a limited type NDI capability.

Now, on a general type thing where a person is expected to make decisions -- well, excuse me. In the other method he wouldn't make the decisions. All he would see is probably an indication and that he would call somebody else to come and make a decision on the product.

In the general sense like in the Army, Navy, Air Force, and NASA some of these other functions where you are expected to know about more than one type function or make a decision, maybe this is not the best way to inspect something, that he should be expected to know about all the functions. He should not necessarily be able to have the expertise to be able to be certified in it or something like this but at least have knowledge of what the other inspection medias have or how their function is or just the general basic idea of how they operate.

Should refresher courses be given? Emphasis should be placed on upgrading new technician developments and so forth.

We ran several computer runs on this to try to extract out of the computer some information on capabilities versus how they fared in the "Have Crack Will Travel Program." We found, which surprised everybody, quite to the contrary that in many cases in the computer -- notice I said in the computer -- it stated that a person had 999 hours of training in eddy current and he fared in the bottom 10 percent of the program. On the other hand it showed that a person maybe had 80 hours training in eddy current and he fared in the top 10 percent. So, I don't myself -- okay, I am going to put a personal note in here. I, myself, don't believe that this is at all accurate. I think that on the form that he might have put down there that his total NDI experience and not necessarily just his training in eddy current. So, therefore, I tend to discredit the findings in the computer.

Okay. Now, what we thought, what the final concensus was was that if you have a poor performer, you might try to upgrade him once or twice and try to bring him up to your expectations. But after once or twice it was kind of trying to put good money against bad in trying to train into a person some type of integrity or ability that he evidently had no interest in performing in the first place.

TRAINING

(4) SHOULD REFRESHER COURSES BE GIVEN?
EMPHASIS SHOULD BE PLACED ON UPGRADING;
NEW TECHNIQUES, DEVELOPMENTS, ETC....

(5) CENTRALIZED TRAINING VS MOBILE TRAINING UNITS?
CENTRALIZED TRAINING MORE COST EFFECTIVE.....

(6) CAN TRAINING KITS BE DEVISED TO PROVIDE "HANDS-ON" EXPERIENCE?
YES, IF COMPLETE
SUPPLEMENTAL

(7) HOW MUCH THEORY TRAINING IS NECESSARY?
ENOUGH TO UNDERSTAND THE MECHANICS OF THE TEST.....

VIEWGRAPH 3

(8) SHOULD TRAINING BE TAILORED TO ACHIEVE CERTIFICATION?
NO.....!

(9) SHOULD THE "TRAINER" BE CERTIFIED?
THERE SHOULD BE A SYSTEM TO ESTABLISH A LEVEL OF QUALIFICATION AND/OR CERTIFICATION FOR NDI TRAINERS!

(10) SHOULD MANAGEMENT/SUPERVISION BE NDI ORIENTED?
YES! SUGGEST POSSIBLE THREE DAY APPRECIATION/FAMILIARIZATION COURSE.

VIEWGRAPH 4

The main type of refresher courses should be on the line of new techniques that are developed in the art, new equipment, maybe some new findings like for instance acoustic emission or low frequency eddy currents, something along this line.

Centralized training versus mobile training units. There are two items here that we found that were more advantageous to have a centralized training-type environment, one being that at a centralized training-type environment the individual was given the greater opportunity of remaining in the classroom environment. He was not interrupted by phone calls, higher priorities that his supervisor might have to have to pull him out of the session to go and do a particular job, this type of thing. Plus the economics of it. We had several gentlemen in the session that had experience in this line. And they informed us that it was more economical to send the people to the centralized training rather than having them travel to the section or to the area of the shop, laboratory, whatever to do the training. There was a difference of about $200 or $100 a person.

Can training kits be devised to provide hands-on experience? Yes, if complete supplemental. What we meant by this is that these kits -- which we took them to be sound on slides. If some people are not familiar with that term it is a tape recorder that is wired up to slide projector. I don't really know the function of it. But the tape triggers the slide projector while it is giving the dialog. It shows a slide and more or less is a show-and-tell type thing. Plus, what would be containeed in this kit would be -- or what it would be geared to is a piece of equipment or a particular inspection media such as ultrasonics. It would give the technique setup of the piece of equipment, whatever it may be, plus a sample that you are to inspect, hands-on-type thing. And it will show pictures of the sample and where you should place the transducer, eddy current probe or how you would set up the radiographic technique, this type of thing. And it would be somewhat more understanding than just possibly reading the book because you would have the equipment and support data there. So, it would be a little bit more understanding than just a text data itself.

How much theory training is necessary? Enough to understand the mechanics of the test.

Now, this goes hand in hand with a prior question. I believe it was 45 percent and 55 percent. There were two trains of thought here, one being how possibly could anybody make or do an inspection if he did not have the complete theory as to what was happening between the part itself. Other people say, why clutter his mind up with this type of thinking when all we want him to do is find a discontinuity or defect.

Should training be tailored to achieve certification? This was quite emotional with me and everybody else. We concluded that training should not be geared to just achieve certification. Certification should be the minimal requirement for doing or functioning or achieving any one particular inspection. Training should be geared to receive the optimum effectiveness in inspection capability. I don't know what else to say.

Should the trainer be certified? There should be a system to establish a level of qualification and/or certification for NDI trainers. Some years ago, maybe 10 or 15 years ago, when the first generation of really informed experts in NDI were coming up, there was not anybody to do any certifying because who knew enough than those type people that could certify. I have no idea.

But now I estimate that we are probably up in our second or third generation of NDI inspectors. This should be a prerequisite. We should not put people in a classroom-type environment of people that have little or no experience in NDI other than what they have read out of a book. There are a lot of things that you read out of a book.

But there is so much more that you learn out of practical experience. And this should be the situation.

Should management/supervision be NDI oriented? Yes. Suggest possible three-day appreciation/familiarization course. I personally have been put in situations where

an individual that had somewhat more authority than I had had gone through an orientation course where it was possibly only three days long and stuff like this. And because of the virtue of his position he naturally thought he knew more than I did. What I would like to suggest on this with the concensus of the forum itself was to not only orientate people that weren't directly involved in NDI but are on a management level to be familiar with NDI, but not only tell them of the capabilities of NDI but also tell them of the shortcoming, what a particular inspection media cannot do as well as what it can do. So, you don't get things like: Well, you didn't find it, why don't you X-ray it, you know, this type thing because any one of these type circumstances or any one type inspection media is not a cure-all for all situations.

Comparison of performance versus training hours. Now, this was the data which we received out of the computer. Based on computer supplied data we found that performance did not improve with increased hours of training. I think I already spoke on this. Performance did not correlate with the level of formal education. We found that in the lower and top 10 percent that formal education outside of NDI -- there was no correlation with the amount of formal education versus their performance in NDI. There was not anything in the computer to tell us what type of education or in what subject or what they majored in or anything like this.

Performance did not correlate with the amount of NDI experience. There again it was already mentioned that people with more than 10 years' experience were in the top 10 percent and in the bottom 10 percent more evidently. And those with less than 10 years were prominent in the top 10 percent. Again, people with more than 10 years' experience were in the top 10 percent.

In fact, it was a primary factor that that is usually where they were at. People with less than two years' experience fell by and large in the bottom 10 percent.

Do you all know what I am talking about?

TRAINING

COMPARISON OF PERFORMANCE VS TRAINING HOURS

* BASED ON COMPUTER SUPPLIED DATA

1. PERFORMANCE DID NOT IMPROVE WITH INCREASED HOURS OF TRAINING.
2. PERFORMANCE DID NOT CORRELATE WITH LEVEL OF FORMAL EDUCATION.
3. PERFORMANCE DID NOT CORRELATE WITH AMOUNT OF NDI EXPERIENCE.
4. AGE HAD NO BEARING ON PERFORMANCE.

VIEWGRAPH 5

RECOMMENDATIONS

1. EVALUATE EXISTING TRAINING PROGRAMS.
2. EVALUATE QUALIFICATIONS OF INSTRUCTOR.
3. EVALUATE TRAINING MATERIALS (TEXTBOOK, MANUALS, AIDS, ETC.)
4. ESTABLISH A SYSTEM FOR NDI TRAINEE SELECTION.
5. MORE DETAILED INPUT DATA TO COMPUTER.

VIEWGRAPH 6

Again, performance did not correlate with the amount of NDI experience. Those with less than two years' experience fared better than those with over 10 years' experience.

Age had no bearing on peformance. Here again just like the formal training, the ages were scattered from one range from the young to the old in the top 10 percent as well as the bottom 10 percent.

Recommendations: Bernie asked for some recommendations that we might give to him or suggest to him in regards to the fact that if he should run --- in the terms of training, if he should run this program again, what were some of the things that we suggest could be changed.

Evaluate existing training programs. What we meant by this is again the integrity and the experience level of the instructors as well as when you go into a laboratory or a shop, whatever it may be called, that you check the credentials of the supervisor even if he is tested on the reliability program or not, that you go in and test the credentials of the supervisor to find out if he expects the best quality out of his people versus let them do it as long as the paper work is filled out, that we have an integrity-type situation where the supervisor will ensure that his people are doing the best job.

Evaluate qualifications of the instructor.

Evaluate training materials, textbooks,manuals, aids, so forth. This was meant by the textbooks, manuals and the aids, etc., that are in the "Have Cracks Will Travel Program."

Establish a system for NDI trainee selection. I think the personnel people have already covered this. Plus, on our very first slide we showed that these are the people that we would like to train and this is how we would like to train them.

More detailed input data to the computer. When we fill out this form, we are not saying more pieces of information but more explicit pieces of information. Such

as, when it says on a particular form like for eddy current, specimen A, or whatever it was, that he put on there eddy current training rather than NDI training because otherwise there is no correlation. He might have had 10,000 hours training in radiography. I don't know what value that would be in eddy current. That way we would have more correlation to find out just how much training is effective in any one particular inspection media.

Okay. Are there any questions on what we have covered?

UNIDENTIFIED SPEAKER:

You kept saying supervisor. Did you mean instructor?

MR. DORGAN:

No. In some cases when the person or the individual -- I say person because we have got a lot of ladies in NDI in the Air Force -- but when that individual goes to a working environment, he is still on a type of training like O.J.T. even if it is just orientation. And a lot of the emphasis is put on what the supervisor expects of his people in the way of a learning environment.

UNIDENTIFIED SPEAKER:

I would like to clarify a point brought out about the question of the amount of experience in NDI.

MR. DORGAN:

He wants to clear up a point in the question about experience in NDI.

UNIDENTIFIED SPEAKER:

According to the computer run, it showed that those people with less than two years' experience in NDI acutally did as well if not better than those with more than 10. I would like to refer back to the first session when talking about personnel. Is that the data that the gentleman from the back of the room was referring to when he talked about in excess of 10 years experience in other fields?

The question was on the correlation between the experience, was it NDI, or was it in other fields? This correlation was the prior experience of other fields of more than 10 years and here in the NDI field. Those people were in the low performance area. The other correlation we did not look at.

UNIDENTIFIED SPEAKER:

Well, the reason I am confused on this point was because in the session I was in, personnel, we tried to get some figures as to how well a person performed during the first four years of NDI if that was his first job, right off the street, compared to the man that had been in some type of industry job or aircraft maintenance job for a period of four or five years and then went into it. Data was not available. Now you are saying that those with 10 years did perform.

UNIDENTIFIED SPEAKER:

Yesterday when I went into Personnel they had a different listing and not a complete a listing as some of the other task groups. There is more information available than was in that task group.

UNIDENTIFIED SPEAKER:

Can you clarify something for me, John, please?

What I would like to ask is: My understanding of the data of reliability against experience -- my understanding of the situation on this data was that reliability in finding cracks against number of years of experience and against number of hours of formal NDI training was that it was a scatter, that you could get one guy who had 10 years' experience in NDI who might not be very good at finding cracks whereas another one with 10 years could be very good. A guy with two years' experience in NDI could be very good or he could be not so good. There was a complete scatter.

Is this true?

MR. DORGAN:

We found that it was dominant that the people with less than two years' experience fared a whole lot better than those that had over 10 years' experience.

Is that true, Bernie?

MR. BOISVERT:

This is a rough look. We are going to have to clarify this. But some of the printouts that they had indicated that the higher performers were two years or less.

MR. DORGAN:

That is the way the trend looks right now.

UNIDENTIFIED SPEAKER:

Because the comment is that if the case is as I put it, then the fact is that you haven't got a selection procedure and that your selection from a random population will explain that scatter.

UNIDENTIFIED SPEAKER:

Bernie, you need to be able to distinguish between 10 years of experience and one year of experience 10 times.

MR. BOISVERT:

Yes. That is a good point.

UNIDENTIFIED SPEAKER:

A word of caution about your terminology correlation. You mentioned the performance didn't correlate with the level of formal education or NDI experience.

Are you assumng a linear regression model? If so, why?

MR. DORGAN:

Chuck

MR. HELLIER:

No, we were not assuming a linear regression model. It was just extracting the bits of information that we had on the computer run-off sheets.

MR. BOISVERT:

They need the question repeated.

UNIDENTIFIED SPEAKER:

My question was: Did he assume a linear regression model? If so, why?

MR. DORGAN:

No. There was no linear.

Okay. That is all the time we have. Thank you very much. I would really like to thank everybody that was in our session for the cooperation and the really good discussions that we had. Thank you.

III. OPERATIONS

TASK GROUP LEADERS:

E. O. Lomerson
E. C. Gustely
R. J. Meyer

MR. E. O. LOMERSON, Summary on Operations: Bernie, I really couldn't have picked three more impartial people. Ed Gustely, Richard Meyer, and myself have no background at all in the service portion of this. So, most of the stuff we are giving you are the comments that we had gotten from the 18 or so people from the various walks of life here, the field, the depot, the Army, the Navy, and the Royal Air Force, plus industry.

The first thing we tried to do is to figure out just what the objective was. The operation didn't give us too much, unfortunately. I don't think the questions were that enlightening for use to figure out what we wanted to do. So we came up with the objective of What Management tools -- and I guess the Air Force and military have different terminologies than I used, but whatever their terminology would be -- What Management Tools Can be Used To Improve NDI Effectiveness. So, this is what we tried to go after.

During the various discussions we aimed in on problem identification. We have got a list of what we feel were the problem identifications. Now, the first one is Inadequate Recognition of the NDI Personnel. Obviously, this is a beautiful motherhood statement specifically for an NDT gathering like this. But this specific statement came up many times, and it was felt to be important enough to put as first.

Now the organization in the air force is such that the way the commands come down, the NDI inspection appears to be able to be overridden or enough pressure is put on that they will maybe inspect a little bit different than if they had a little bit more of authority.

Unrealistic work Schedules, being number two, was discussed several times. The work schedules coming down

OPERATIONS

OBJECTIVE

WHAT MANAGEMENT TOOLS CAN BE USED TO IMPROVE NDI EFFECTIVENESS.

VIEWGRAPH 1

PROBLEM IDENTIFICATION

- INADEQUATE RECOGNITION GIVEN TO NDI
- UNREALISTIC WORK SCHEDULES
- PERSONNEL NOT EXCLUSIVELY ASSIGNED TO NDI
- NONQUALIFIED PERSONNEL ASSIGNED TO PERFORM NDI
- NDT TECHNICAL (DEPOT) LACKS THE AUTHORITY TO MONITOR NDT FIELD OPERATIONS
- NDT TECHNIQUES (T.O.'S) PROVIDED TO THE FIELD ARE NOT NECESSARILY APPLICABLE UNDER FIELD CONDITIONS.

VIEWGRAPH 2

as supplied by the depot were such that it was feasibly impossible to do the inspection in the time allotted. So, therefore, various types of shortcuts, et cetera, had to be applied.

Personnel Not Exclusively Assigned to NDI. In several places it was mentioned that NDT personnel were pulled from sheet metal or other areas and that the NDT was more or less a second-area-type operation. In other words, when they needed something done, they pulled them from the other area. We will get back to that a little bit later.

The fourth is Nonqualified Personnel Assigned To Perform NDT Inspections. Now, I think this was probably the most pushed requirement or problem identification here. Everyone in all three groups said that the personnel doing the NDT inspections were very limited in their certification, qualification, or in their background.

The fifth is NDT Technical -- and when we say NDT Technical, we mean the depot -- Personnel Lacks the Authority To Monitor NDT Field Operations.

It was pointed out that many times the fields are doing one field operation where another does not do the inspection anywhere near the same. Some are more, let's say, reliable or sensitive than in other places.

And, finally, the NDT techniques -- these are the T.O.'s issued by the Air Force. I guess it's a bulletin by the Navy -- provided to the field are not necessarily applicable under field environments. Techniques can be set up in the labs and when they get to the field, they cannot be done under actual inspection conditions. This is both the technique and with the existing equipment in the field.

As a result of these requirements or problem identifications we came up with some of the recommendations that were felt to be important.

One was that NDI personnel should report directly to the chief of maintenance. I guess in the Air Force

OPERATIONS

RECOMMENDATIONS

- NDI PERSONNEL SHOULD REPORT DIRECTLY TO CHIEF OF MAINTENANCE
- NDI TIME SHOULD BE DETERMINED BY DESIGNATED DEPOT NDT ENGINEER
- NDI PERSONNEL ASSIGNED PRIMARILY TO NDT
- NDI PERSONNEL CERTIFIED IN EACH METHOD BY TESTING PRIOR TO PERFORMING NDI
- DEPOT PERSONNEL GIVEN AUTHORITY TO MONITOR NDT FIELD OPERATIONS AND ASSURE CORRECTIVE ACTION
- ALL NDI T.O.'S BE APPROVED BY DESIGNATED NDT DEPOT ENGINEER.

VIEWGRAPH 3

DEPOT RESPONSIBILITY

- PROVIDE SIMPLE WELL DEFINED T.O.'S
- ASSURE FIELD HAS PROPER EQUIPMENT AND PERSONNEL
- SUPPLY SPECIAL TOOLS, FIXTURES, CAL. BLOCKS, ETC.
- PROVIDE CLEAR STANDARDS
- CHECK TECHNIQUES UNDER FIELD CONDITIONS
- SPECIFY REALISTIC TIME FRAME FOR INSPECTION
- PROVIDE TRAINING ASSISTANCE TO THE FIELD
- ASSURE ALL FIELD INSTALLATIONS ARE DOING THE SAME INSPECTION.

VIEWGRAPH 4

right now they are reporting to the fabrication shop. The fabrication shop, since they are required to get these planes turned around and pushed out as rapidly as possible tend as we understand it to put considerable pressure on the NDI people and thus possibly overrule certain types of inspections or persuade the inspectors to accept something that may not be correct.

Now, obviously, going back to the problem of identification where we said inadequate recognition given to the NDT inspectors, this change in organization will not in itself give you that recognition. We feel the NDT personnel have to become knowledgeable, very strong in the NDT inspection. And when they call something wrong, it is wrong. It isn't that well it might be or it might not be. They have got to put theirselves on the line and say this is it and we will back it up to the hilt. Sometimes, obviously, they may be wrong. But what you have got to do is get confidence of the officers in charge.

NDI Time should be determined by designated depot NDT engineers. In other words, if a T.O. comes out and says: Look, we have got to re-inspect this part and it has got to be turned around in two days, it means that under field conditions it can be done. The concensus a lot of times was that some of these T.O.'s are coming down indicating times that are unrealistic. Therefore, to meet the times they are taking shortcuts, doing sampling, or in some way getting those planes back on the line because this is the requirement they are there for. Now, we recognize that there are other problems that supervision has to take care of to make sure the people are working. But we are talking about under the conditions that it is truly unrealistic.

The third item is NDT Personnel Should Be Assigned Primarily To NDT Activity. It is not the habit, or it is not reasonable to assume that a person that has responsibility in other areas and an NDT as a secondary will be capable of being proficient on all of the NDT techniques.

It would be better to have fewer NDT people with good strong NDT training and using this training all the

time rather than a large body of people to throw in that may not be being used from month to month.

NDT Personnel Should Be Certified In Each Method By Testing Prior To Performing NDI. Again, this is what we mentioned before as being the major problem identified, certification. As was pointed out before, we were not interested in how you certify him, just to make sure that they are capable of being certified and doing the job that is intended. This certification is important on both the civilian and the military personnel. It should be to something like 410 or equivalent.

The Depot Personnel Should Be given Authority To Monitor NDT Field Operations and Assure Corrective Action. Now, under this particular case it is felt that the depot has the prime responsibility. So, therefore, you treat them the same as the field should be treated or not treated but should be controlled similar to a vendor from a prime, whereas to assure that they are getting the same kind of inspection from one field operation to another, in addition that the depot should be writing the technique and should be fairly uniform and assure that the techniques are correct.

The last items is somewhat under the same area as the previous one. All NDT Technique Sheets Should Be written And/Or Reviewed Or Approved By Designated NDT Depot Engineers. It has been indicated in one or two of these meetings that in most cases this is being done, however, as sometimes flight officers, etc., without any NDT experience may demand or require certain inspections and go around the NDT engineer in the depot and these types of inspections can get out of hand from time to time.

Now, for the depot we did put a couple items down that we thought we should just mention in passing, that their responsibility should be to provide a simple, well defined T.O. or technique, whatever you want to call it. They should assure that the field has the proper equipment and personnel before issuing such a T.O. They should supply special tools, fixtures, calibration blocks, et cetera when they develop or write the T.O. They should provide clear, `straight-

forward standards that can be interpreted relatively easily. They should check techniques under field conditions, actually at the base. I think the Navy has indicated they have a way of sending their T.O. or bulletin out to be approved by some field operation before it gets issued. They should investigate and specify a realistic time for inspection.

They should provide training assistance to the field. And, finally, they should assure that all field installations are doing the same inspection whether this is by monitoring the field operation. I don't want to get into politics in here, but what they should be able to do is get out into the field and actually do an audit to make sure that the field is doing the inspection correctly and if not, have authority to take and implement corrective action.

Relative to the questions listed under Section 3 covering time and motion studies, work and rest periods, task sizes, et cetera, it was concluded that each job was unique and should rest on its own merits. In other words, we could not define specifically the proper task size or the rest periods, how long it should take before you take a break on the thing. The NDT supervisor should be thoroughly knowledgeable in the applicable NDT methods and it is his judgement --- it is up to him to decide this. This is what he should be paid for and should control. However, it should be recognized that the task time related to a specific NDT inspection is important both to obtain some type of an efficiency but more importantly to establish a realistic schedule.

So, therefore, Bernie, I am sorry we could not give you specific answers to your questions.

I think that is it unless there are any questions.

UNIDENTIFIED SPEAKER: Yes.

The -36 manual and lots of T.O.'s are written by the contractor on his product. I still think that that should be encouraged here and not just turn it over to the Air Force.

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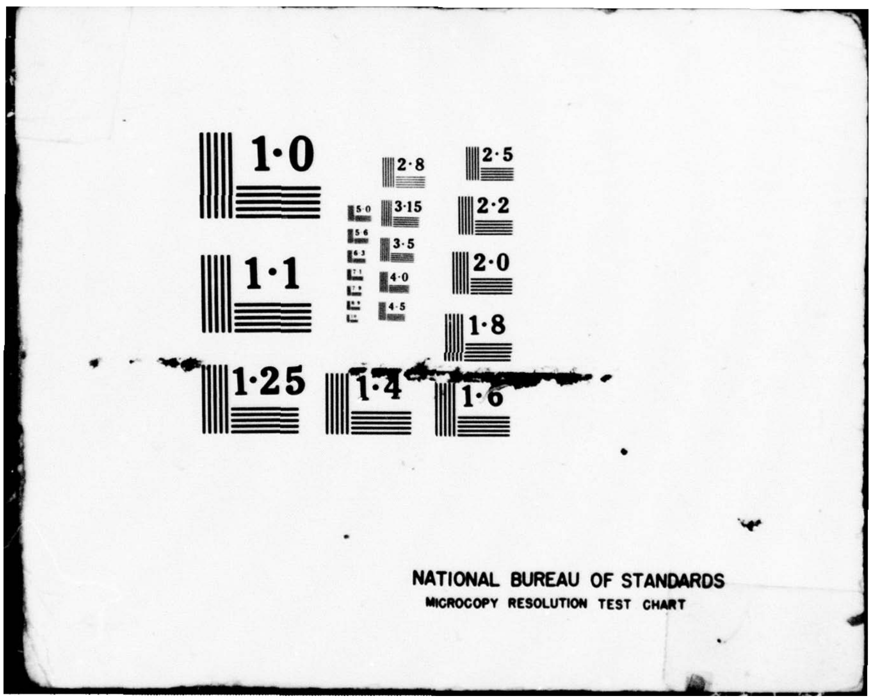
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NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

MR. LOMERSON:

We recognize this, but we said that the depot should write or review and approve.

UNIDENTIFIED SPEAKER:

Well, like I said, the contractors write and issue through the AFPRO and the Air Force SPO System. Many T.O.'s don't go that route. However, those documents are taken out and actually demonstrated on a vehicle where you measure the times and how long it takes to get to the article and to make sure it works. That system I don't think should be negated and suddenly everything goes through the depot.

MR. LOMERSON:

We felt that the depot was more or less the prime for the field. But we recognized that a lot of this is done by industry. We felt that if the depot is going to have the responsibility to assure adequate inspection that they should also have a crack at the technique. Now, whether it is a functionary approval or otherwise at least they should be there because they may be out in the field assisting the inspectors there to implement it.

Do you see what I mean?

UNIDENTIFIED SPEAKER: Yes.

UNIDENTIFIED SPEAKER:

I just wanted to say that the depot NDI engineer does have responsibility for the -36's regardless of who writes them. Even though a contractor will write them, the depot has got to have responsibility for publication and implementation.

MR. LOMERSON:

It was informed to us that they could go around them, that they have the responsibility but it isn't a straight line-type of responsibility. In other words,

not all T.O.'s must go through them, just as Ed Caustin just indicated.

Am I right?

UNIDENTIFIED SPEAKER:

They may go by them, but they are not supposed to.

MR. LOMERSON?

This is the reason we pointed this out.

UNIDENTIFIED SPEAKER:

The depot is not in the loop of approval in the development of the T.O. The T.O. is developed and is supposed to be validated by the contractor on the particular model of the aircraft. If in the field they find that a particular technique is not correct, the problem is that there is no feedback between the field and the contractor to get the T.O. changed.

There is a missing gap in the system there that causes delays in remedying problems in the T.O.

MR. LOMERSON:

Would you repeat the question?

UNIDENTIFIED SPEAKER:

I was saying that the contractor develops the T.O. and is supposed to validate the techniques that are identified in the T.O. One of the problems that exists is if in the field operation at some point you find that the T.O. is impractical from a field standpoint, the method of getting the T.O. changed has a gap in it. And this causes some heartburn I am sure, between the contractor and the NDI personnel, the director of maintenance, or whoever in the field. And this is where the problem, I believe, needs to be reviewed and some corrective action taken.

MR. LOMERSON: Thank you.

UNIDENTIFIED SPEAKER: My question is really directed at Bernie.

In these presentations -- we have not heard them all yet. But it seems like there is going to be a great deal of overlapping like, training talks about certification, operations has talked about certification and training, and we wonder whose recommendations should be the final recommendations. You are going to have possibly conflicting recommendations. And I am just curious as to how you are going to handle that.

MR. BOISVERT:

We like these conflicting recommendations primarily because it gives us some options. We may merge the two together and reach a halfway point. But we do want or we encourage conflicting recommendations. This is really why we are here. I do want to just point out to both Ed Caustin and Roy Wolford according to AFPI71-159 and Mil Specification, MIL-M-38780 it says Thou shalt submit that Tech. Order manual to the depot. And if we do not like it, we don't buy it off. And we have got the SPO ASD under our thumb. We say: Hey, that's not acceptable to us. We say, do it over until we like it. We also have a feed back information. If you look in Chapter 1 of our Tech Order 33B-1-1 when John Dorgan wanted his people to come up with a better method of doing an inspection or come up with a part that could be inspected with NDT, they fill out a form and it goes into the depot. If you are still under contract and, in some cases Elmer has contacted you through DSM to say, hey, Mr. Wolford, develop us a procedure around this. We do have a feedback system. It doesn't always work, but, hey, it is there. It needs sharpening I will admit but we have a system.

UNIDENTIFIED SPEAKER:

I was wondering whether it is universally true in industry that NDI personnel report directly to management rather than to a production section of some type.

MR. LOMERSON:

Ed, why don't you take that.

MR. CAUSTIN:

In industry, usually they report to quality control, which does not report to production but on the same level as production or engineering or any of the other major disciplines. We have found this not to be true in the Air Force. Of course, the Air Force or the Navy, the military always insists upon us in industry to have that type of organization. They recognize what is a good organization, but they don't want to do it.

MR. LOMERSON:

They recognize that they need that qualification, too.

UNIDENTIFIED SPEAKER:

Ed Caustin builds military airplanes. I just wanted to indicate that for commercial aircraft the Federal Aviation Regulations also require that the inspection be separated from the manufacturing operations.

MR. LOMERSON:

Are there any other questions?

Thank you.

IV. CERTIFICATION

TASK GROUP LEADERS:

J. A. Moore
G. C. Wheeler
S. A. Wenk

MR. G. C. WHEELER, Summary on Certification: Well, we did not address ourselves directly at any time to the specific questions. Although, after we got done I made some effort to try and pull together answers relating to the questions that Bernie and Bill asked. We didn't really have to because the first session started out so strong. And we just went from there. It was quite apparent that everyone had a firmly fixed idea about certification and whether it was good or bad. With my particular bias I was glad to find that everybody was on my side.

I think the reason that I was nominated to stand up here was that I make a poor target in case of tomatoes.

I have never seen so much unanimity on certification before. What I am going to do is give you the punch line first because as I said there was complete unanimity that certification would greatly improve NDI reliability.

The difficulty was to get people to try to quantify why they felt that way. It is a highly emotional issue. Everyone was completely in agreement, but we really couldn't get any quantification for a while.

Ultimately, we asked the computer some questions. And specifically what we asked was: What proportion of the upper 25 percent and the upper 10 percent in the POD's, what proportion of these people was made up of Base 11's the people who had some certification. And what we found was this: The Base 11's made up about eight percent of the total of those who were tested. But 37 percent of the top quartile in the POD's --

CERTIFICATION

CERTIFICATION WOULD GREATLY IMPROVE NDI RELIABILITY

BASE 11's = 8% OF EXAMINEES

BASE 11's = 37% OF TOP QUARTILE

HOW:

- BASED ON EXAMS
- REQUIREMENTS DEVISED BY RECOGNIZED EXPERTS
- PROGRAM ADMINISTERED BY RECOGNIZED EXPERTS
- REQUIRED OF ALL PERSONNEL PERFORMING OR EVALUATING TESTS ON "BIRDS"
- SIMILAR TO SNT-TC-1A WITH PRACTICALS LIKE "HAVE CRACKS WILL TRAVEL" PROGRAM.

VIEWGRAPH 1

CONSIDER CENTRAL CERTIFICATION BUT NOT TO DELAY CERTIFICATION.

NDI SHOULD BE IN QUALITY MANAGEMENT WITH RECOGNITION SUITED TO SAFETY RESPONSIBILITY.

"MAKE IT HAPPEN"

VIEWGRAPH 2

UNIDENTIFIED SPEAKER:

Can I interrupt a minute? Could you tell us what Base 11's are?

MR. WHEELER:

Base 11's are that one group that were certified. Thirty-seven percent of that top quartile was made up of those people. I think we should not have questions during the talk in order to get the thing through. I will answer questions later.

UNIDENTIFIED SPEAKER:

I would like to ask you what you mean by certification of existing --

MR. WHEELER:

Let me answer that later because that is a long answer.

It seems quite clear from the data that there is an effect of certification on how well people perform. There are some specific glitches, I think, in the computer. We found things like people with 900 hours of training, and they hadn't been born yet. There are some glitches I think.

These averages though kind of spread out some of the glitches and let you look at the general case rather than the specific detail. If anyone wants a specific detail, I can still dig out the data.

Some of the questions that were asked by Bernie and Bill and which one can always ask is: How can you do the certification. Now, this gets to the point of being more of an opinion because there is not an awful lot of data on that kind of question in the computer. So, what you are getting now are opinions that I think represent the opinions in general of the groups that we talked to.

The general opinion seemed to be that the certification should be based on exams. You can ask yourself, how do

I know that certain material has been covered unless you have an examination.

The general feeling also was that there was a problem with all kinds of qualification activities if they are not done by someone who is a recognized expert. Now, you can ask what is a recognized expert. We left it purposely vague because there are a lot of definitions. I think you are aware that there are places to go for centralized training where at least you can say: I got this body of knowledge. It is a documentable body of knowledge. Certain questions were asked. I know the answers to those questions.

One such place, of course, is the ASNT Examinations. So, there are ways to get recognition as an expert.

Another problem that seemed to be very common is: How should you administer this qualification certification program. And again we resorted to this generality that it ought to be done by recognized experts. Clearly, it doesn't work very well if you are dealing with a boss who doesn't know the first thing about NDI.

And then there was a question of who should be required to certify. Now, we thought that this described it pretty well. We thought certification should be required of anyone who was practicing NDI on flying objects.

I think that in -- I didn't hear any objections to this in any of the sessions.

We also felt that the certifications should embody some of the things that have been embodied in SNT-TC-1A because that is an easy way to describe that you should have some kind of an examination on the theoretical aspects of the method, something about the specific equipment and procedures that you have to deal with, and also some demonstration of a practicability to apply these procedures and these pieces of equipment to this particular piece of hardware which you have to inspect.

We thought that the idea of using protable or semi-portable test samples like the "Have Cracks Program" was a good one. It is not necessary we don't think to cart these things around the country. You can ship them and get the results back and process the data in a central point. This provides a uniform evaluation of the results and, I think, simplifies the number of pieces that you need.

The question was asked whether certification should be central or dispersed. We felt it couldn't really be answered. Centralized certification certainly has some advantages. It gives you uniformity in the program. It probably allows you to prepare a more detailed program, perhaps do it better. But we felt very strongly that any central certification program that was considered should not hold up, not delay the implementation of some certification program at every place where NDI is used.

We also heard a lot of things about the organization of the NDI effort. And we thought that that should be addressed, not having realized that so many other people would address the same problem. So, we have addressed it. We felt that NDI should be in quality management.

We also want to make a point strongly that -- out English friends made the point very effectively -- that one of the prime things that you need is a recognition of the importance of NDI because it is a safety responsibility.

This is essentially the story. I guess I added one line here which the rest of my team doesn't know about yet. I think you have got to do that.

"Make it happen." I heard some comments and discussions yesterday that indicated a defeatist attitude. We have got all this hierarchy above us, and there isn't really much we can do about it and so on. I think that if you take that kind of attitude, that is how it stays. You have to go to and make it happen. That is all I have to say.

Questions?

UNIDENTIFIED SPEAKER:

Was it the opinion of your group that the Air Force should have a certification program?

MR. WHEELER: Yes

UNIDENTIFIED SPEAKER: Was that unanimous?

MR. WHEELER: I asked for negative opinions. And there were none.

UNIDENTIFIED SPEAKER:

Will you clarify certification: Is it to the existing requirements; that is, SNT-TC-1A which includes practical examination? Or is it something that we have not done yet like the demonstration program as part of the certification?

MR. WHEELER:

As I understand what was done by this one group, they -- the question was: What is meant by certification in this case. I talked about some certified people. The question is: What is that.

As I understand it, these were a group of people where selection of the personnel is exercised and where they are given -- let me back off -- where they have initial training. They are then considered nominally certified. But when they reach the base, I will say, they are treated as trainees. And they are not considered by the base to be certified nor do they do any NDI on their own until they have had considerable on-the-job training.

That on-the-job training requires a formal qualification examination. And they don't do NDI on the aircraft until they have passed those qualification examinations.

Is that essentially correct? It is a local policy at one location. Is that essentially correct?

UNIDENTIFIED SPEAKER:

The only thing that is different is that the training was on the base.

UNIDENTIFIED SPEAKER:

Is there any thought in recognition of the certification both in military and in civilian production? Would the same certification be recognized by the military as well as civilian production?

MR. WHEELER:

The question was: Will these certifications be the same for both military and civilian and will they be accepted by the other organizations. Is that right?

UNIDENTIFIED SPEAKER: Right.

MR. WHEELER:

We did not address that particular problem. But it would seem to me, speaking as an individual, that if they are suitable to the task, they ought to be the same.

UNIDENTIFIED SPEAKER:

May I speak for the industry, please -- the utilities?

From the utilities standpoint -- I speak of Georgia Power Company -- we recognize all training regardless of whether it is obtained in the military or not. As a matter of fact, we like to have military. However, just by virtue of the training they are not automatically placed in the job. They are administered various qualification tests because we adhere to the SNT-TC-1A.

MR. CAUSTIN:

This is a comment, not a question. The other day during the presentation they were talking about -- one of the questions came up -- what do you do with these people that are low performers, what airplane do you allow

them to work on. Certification gives you folks the opportunity to eliminate those low performers from the NDI circuit. *And that is the main reason for* certification.

In my point of view it allows you to get rid of the low performers.

MR. WHEELER:

We completely agree.

MR. DORGAN:

This is more of a statement than a question. Being in the military, we are going to be up against somewhat of a problem and we are opening up some type of a Pandora's box when we keep training these people, we keep certifying these people. We are going to certify ourselves out of business because as soon as industry realizes we have got these highly trained and certified people within the military where do you think they are going to go to earn the money.

So, these are some of the things we are going to have to recognize and kind of reward these people for the education and certification they are going to get.

MR. CAUSTIN:

You are talking about where they go. I think the industry would like to have the Air Force to have certified people. I think it would lessen our problems.

UNIDENTIFIED SPEAKER:

I have a question. George, you mentioned that in the top 25 percentile 37 percent of the samples that were taken were certified individuals. Do you have any feel for the number of certified people in the lower 10 percent bracket?

MR. WHEELER:

We looked at that only for one of the examinations. And I don't recall now which one it was -- But it was Sample F on sonic test. And that was one in which no certified people appeared in the top 25 percent. So, we looked at the bottom 10. And there were three of them in the bottom 10 on that one examination. There are some anomalies in the data as I said, and that is one of them.

UNIDENTIFIED SPEAKER:

The reason why I asked that was in reference to Ed Caustin's statement about implementing a certification program and therefore you would eliminate low performers. I don't agree. I only feel that this is going to happen when the certification program is correctly applied. And if we don't have a certification program that is proper and if it is not implemented properly, it is not going to eliminate low performers.

MR. WHEELER:

Well, if you don't do it right, it is not going to accomplish anything. But I think that in general the application of a certification program which usually means some kind of test administered at the end, tends to weed out the poor performers. A lot of them just won't play. They won't be interested if they know they are going to be examined at the end.

Sam is pointing out that the general level of performance on this Sample F on sonic testing was poor. The mean detection for a half-inch radial flaw was about 15 percent.

There were a couple others back there. Don.

UNIDENTIFIED SPEAKER:

This is a comment in that all certification programs that I have read or to hold the documents indicate that the certification implies -- the word implies responsibility of the employer. In other words, he accepts the

responsibility of doing this certification. The question is who is the employer in the Air Force or who is going to accept this responsibility. Is it the depot, or is it the Air Force in general?

MR. WHEELER:

I guess my answer to that is -- it is not something we dealt with yet -- it depends on how you set it up. If you set up a central certification program in the Air Force, it is going to be one thing. What we are advocating is you should do something at every depot. Do not use unqualified people. It is easy to be in favor of, I realize, and harder to implement. But if you don't try you are never going to get there.

UNIDENTIFIED SPEAKER:

You made the statement, down where you added on, "Make it Happen". You are one who has been pretty successful, in fact would you give us some suggestions on how to make it happen without losing your job.

MR. WHEELER:

The question was to the effect that I have been able to make it happen myself and how should you make it happen. I will see you later.

Obviously, there is no one way to do it. As it happens, I don't have to have anyone certified to anyone else's requirements. I certify my people because I think they ought to be. And I find it useful.

Yes, sir.

UNIDENTIFIED SPEAKER:

I would like to go back to the previous question. In the Air Force we have to look to our program manager for NDI to answer that question of who is going to initiate certification in the Air Force.

MR. WHEELER:

His question is who is going to initiate the certification in the Air Force.

MR. BOISVERT:

I have been told we will have a certification program. It is a matter of working out the details and so on. How we are going to do it, who is going to administer it, these are details we still have to be taking under advisement. We are still arguing between Tom Cooper sitting there holding his head and shaking yes and no. But there will be a program. There will be a program of, rather than certification, we are talking about identifying technician proficiency.

If I could identify the marginal performers, if I can identify those performers that need additional training or additional upgrading in capabilty, and if I can identify my high performers, people that I can trust on fracture critical parts, a green card inspector if you want, then we will be one step forward.

MR. WHEELER:

Let me come back a minute to the question Mickey asked. I didn't mean to slough it off particularly. I think there are a lot of different answers to different situations.

The thing I would like to say, though, is that the kind of data that is available here -- although, it is pretty sparse in this case -- if you can find more data like that -- and I think you can, perhaps not on such a broad basis, but I think you can find evidence that certification does indeed help. And if you cart that around through your management, particularly if you have a little trouble sometime and someone gets hurt, which I would not advocate as a way to have it happen, but that helps. That really helps.

Anything else?

Thank you.

V. EQUIPMENT

TASK GROUP LEADERS:

Ron Selner
D. L. Conn
R. M. Neufeld

Mr. Ron Selner, Summary on Equipment: I gave a lot of thought about how to summarize this. I thought about going over the questions one by one making specific comments to the particular questions. I sat and listened to the tapes last night for about two hours and decided that was an impossible task to get too many summary-type answers that a lot of people agreed on. So, after sitting and listening to the tapes for a long period of time I read through the notes and began looking for similar comments on certain issues, certain parts of the equipment program. And not seeing too much continuity there I went to bed, got up rather early this morning and sat and mulled over it and said I think Bernie would appreciate it if I winged it.

Really what I did was I came up with mostly general comments, general suggestions for how our group felt or the three groups that we had in our session on equipment felt about the equipment area in the NDI reliability program. So, I am going to show you some general comments first. In the latter part we will have some specific comments.

Now, we weren't originally assigned the task of talking about standards. in fact, we tried to avoid it. We did the first two sessions. We got started on the third session and some gentleman said, "I came in here strictly to talk about standards." So, we opened it up. We kicked standards around for about 30 minutes. So, we will have a couple of comments to make about standards.

I think what I would like to do is just go through without a great deal of detail and open it up to the floor to see what the audience thinks about it later on. There was much comment about automated equipment, how much, when, where, and how. How much intelligence should be built into that system? Should we take away

the complete control of the operator and make it possible to press a button to center the equipment, number two, press another button and complete a scan, and number three, press another button and accept or reject with some built-in intelligence in the system.

Once we got past an automated system there wasn't that much general agreement. But, basically, there was considerable agreement in that we need more automated systems when practical, of course, and when economically feasible.

We certainly cannot devise an automated system for every testing situation that occurs or is spelled out in the -36. But there are many high volume-type inspections that lend themselves very well to automated systems and certainly not only would improve, speed up the results, that would improve the reliability.

When we get to the topic of combining the search and the flaw characterization operation, again it seems to follow quite naturally that is we have a high volume inspection system -- now, we are talking about in-service inspection. There was some disagreement to having a combined search and flaw characterization system as far as industry was concerned. But as far as the Air Force for in-service inspection it would be very helpful if we could combine the search and the flaw characterization operations on our high volume automated systems applications. That is number two.

Okay, now we get into a slightly different topic. We talked a lot about having more automated systems, of course, which add to the cost. We talked about adding and implementing flaw characterization into the operation to make it more intelligent, to hopefully increase our reliability. This is great if we can afford the system in the beginning. But we have also got to realize that by adding more complexity to the system and more extensive systems in the beginning, we are going to add to already existing problems of repair and life policies. In other words, when the equipment gets 10-15 years old, it craps out and we don't have anything programmed to replace it. So, it is felt like if we do implement more automated systems and more

EQUIPMENT

EQUIPMENT IMPROVEMENTS:

1. AUTOMATED SYSTEMS
2. COMBINED SEARCH AND CHARACTERIZATION
3. UNIFORM REPAIR AND LIFING POLICIES
4. STANDARDS - REFERENCE
   - AUTOMATED, INTELLIGENT SYSTEMS
   - MANUAL SYSTEMS
5. PERMANENT RECORD

VIEWGRAPH 1

6. VISUAL DISPLAY

5. & 6. DESIRABLE IN AUTOMATED SYSTEMS FOR OPERATOR VIGILANCE

7. PROGRAMMING
   - CARDS
   - CHIPS

VIEWGRAPH 2

complex intelligence systems, we better have more uniform repair and lifing policies. By this I mean that if we have an X-ray system that breaks down, it would be very helpful if we had a very uniform policy on what we do to repair this system. Some bases send it to PMEL, some bases get it repaired locally at an electronic repair outfit, some send it back to the manufacturer. Right now there is not any really clearcut repair and lifing policies that we could see in the Air Force. So, it would certainly help if we are going to more expensive and complex systems if we institute some kind of repair and lifing policies.

It was also felt that if we add more complex systems, more automation to the inspection process, we better make darn sure that we provide standards. This is particularly a 'must' situation for highly automated, complex systems.

It was also felt that in addition to this in many instances in practice today in the -36 a particular inspection procedure spells out a standard. Now, the question is where do you get the standard and how do you reproduce it. There is no one place where we can go to get that standard. So, if we want to have a standard for a particular inspection set up, we have to make it or have it prepared locally or find somebody that might have one that is similar to the part that we are inspecting. So, it is felt that the manufacture of standards, particularly in high volume inspection areas and in other areas where they would be extremely useful in increasing your reliability for example in the introduction of new type components -- here I am referring to composite skin materials, composite skin not only over skins but also over honeycomb areas. It is almost a must that we have a standard. And where do we get it? It was suggested that the logical way to do this might be to write in to the basic procurement document, when you buy the system, you also buy some standards. Just like we are also buying the -36's now. We need to implement a better reference standard system.

The next comment kind of goes along in line with many factors. But it is felt like if we introduce a lot of

complex, highly automated systems, we are also going to increase the amount of boredom on the part of the operator. We have got to keep this guy alive. We don't want him to just go out there and press buttons.

So, there was a general concensus that it would be highly desirable in many cases, again the situation has to dictate it, but wherever possible and practical that permanent records such as strip chart reportings, C scans, maybe just a sketch of the part being inspected with the location of the defects plotted, some kind of a visual display picture, something that you can go back to. This is highly desirable when you are working on new components or areas where you do not have a very good expertise, and you are trying to get your data. We need baseline data. We also need to keep the operator vigilant. We feel like some kind of permanent records wherever practical and feasible are needed. Along with keeping the operator vigilant, we also felt like in many cases to assist the operator out in the field that some kind of a visual display would be most helpful. This could take the form in most cases of a cathode ray tube presentation. Whenever ultrasonics is being used, a meter, the use of eddy currents, some kind of a light. Something has got to keep this operator vigilant. We just cannot let him go along and press a button.

If he doesn't have any real way of knowing that the test is operating, we are going to put him in trouble and put him to sleep. So, along the lines of keeping the operator vigilant and not making his job one of boredom, we felt it was desirable to have some kind of a visual display.

And those items five and six, the permanent records and the visual displays we felt like were particularly desirable in the automated systems for operator vigilance. And the latter case, of course, is: The permanent records are desirable when you are trying to establish some kind of a base line.

One other item that kept coming up, which is kind of directly opposite to the problem of making our equipment more automated, more complex, was a lot of comment

about simplicity. We want to make this thing do more, build in more reliability, have it to have more intelligence; but for God's sake keep it simple. Well, it is kind of hard to keep something simple if you keep adding more to it, keep adding more functions. But it is felt that for many of the routine inspections that some kind of programmable material is needed to increase the reliability. And this would also make it possible for you to go and do the equipment setup in some kind of a reproducible and some kind of a highly reliable manner.

Some of the things that were kicked around and some of the general ways of programming this so we could go back and set up our equipment to do the test would be in the form of a card or a chip. Now, we are talking here primarily about the electronic controls, where do we set the gain, what frequency do we put it on, how do we take that data, what do we do with that data after we get it. So, there was some talk about cards and chips. Now, of course, programming is another problem. When you start going into programming you get into the complexity. But there are some situations where you have high volume inspections where it would be feasible and practical to introduce some kind of programming.

Those are the basic summaries that we came up with. I think at this time we would like to open it up to the floor for some general comments.

Would anybody like to make a comment?

Yes, sir.

UNIDENTIFIED SPEAKER:

On the uniform repair policies --

MR. SELNER:

What the gentleman said was: If they don't change the equipment for the next 10 years, they would like to see some form of a uniform repair policy.

Yes, Don.

UNIDENTIFIED SPEAKER:

I didn't sit in on any of your sessions because we were busy with our own, but one of the things that was not mentioned in your talk or didn't seem to be discussed was it appears to me that like for certain eddy current inspections or ultrasonic inspections you need specific or odd-shaped probes and holders.

Now, does the manufacturer supply those with the T.O., or who fabricates these special devices?

MR. SELNER:

Yes. This was brought up along with the question of standards. Generally speaking, probes and aids for accomplishing the inspection like various angles or manipulators or guides, templates and the like can be obtained fairly easily from the depots. That is not that big of a problem. That is my feeling and what the general feeling was. This was discussed. This might be a problem that I am not aware of and some of the other people were aware of. It is not as big of a problem for example as that of standards.

UNIDENTIFIED SPEAKER:

May I make a comment -- Pratt and Whitney Aircraft. You must have Grand Master, especially on engines. The Grand Master and all of the reference masters can be bumped against that Grand Master so all the bases have exactly the same thing. So in the event one gets lost or damaged or destroyed, you can go back to the Grand master and everybody is conforming exactly to the same reference masters, the same probes -- especially in eddy currents.

MR. SELNER:

Your question is kind of -- your statement, right. You are talking about a Grand Master as far as equipment goes, probes?

UNIDENTIFIED SPEAKER:

The manufacturer, vendor, usually makes reference masters. There must be a Grand Master to this manufacturer. And all of the other masters that are sent out to the field must be checked and calibrated and correlated with that and sent to the field. In the event one of them gets lost or damaged or something, another one can be manufactured at the manufacturer; i.e., Pratt and Whitney, General Electric or whatever. We have experienced this quite a bit. The military seems to have a tendency to lose things and damage things. There are many times that we have to have them make duplicate orders. And they have to have something to go back to. You can't go out to some vendor and have them make something which is similar to it.

MR. SELNER:

That is a good comment.

Any other comments or questions?

UNIDENTIFIED SPEAKER:

I am just goig to add that one of the questions that came up repeatedly with that one outfit wants a very complicated instrument with a microprocessor in it. The next one wants a simple one with an on-and-off switch. One of the comments we got repeatedly from the vendors, equipment manufacturers is that they can't really afford to develop just a few instruments. This is a question that was thrown out: Who is going to develop these new instruments, who puts the money in to develop them?

MR. SELNER:

Just like in everything, if you get one thing, you lose something else. So, you have to trade things off.

Yes, Don.

UNIDENTIFIED SPEAKER:

In preparing the T.O.'s or the procedures, I might be wrong but it appears to me that the government's statement says that you have to use equipment that is in the inventory. Now, how does the Air Force get other equipment which is, say, on the market which may be better than the equipment which they are calling for to do the job?

MR. SELNER:

Do you want to tackle that one, Bernie?

MR. BOISVERT:

Well, first of all we are limited to our budget. It would be lovely if I had unlimited bucks. I could do a lot of great things. We just don't get unlimited bucks. The spec really reads - it says: Hey, we have existing equipment. We have ultrasonic equipment, eddy current equipment, X-ray equipment, so on. If we have brand "X" and you feel brand "Y" is necessary and you can prove it to me so I can go satisfy the bean counter and get some bucks to buy brand "Y", then there is that option. But we, I, and I believe everyone else in here have certain preferences. And I like brand "X". When I pick up the phone and call and say, Charlie, I have got trouble with my unit, he is there johnny on the spot, fixes my unit, and I am back in business.

I tend to prefer him. But that is not the way we can afford to buy equipment. We have to buy the low bid equipment that does this performance criteria. Right now somebody has come in and shown us -- they haven't put it in writing yet and that is the one thing I have got to get on you all about. Put it in writing. They have shown us where one piece of equipment is necessary for a specific job on one of our newer systems. It is going into the TA. And we are going to have that, and everybody else can use it, too. We do encourage this. As new pieces of equipment are developed, we would like to see if you can show us where this would do the job and the other one won't. But I can't drive a Cadillac when a Ford automobile will do.

That is really my guidelines in buying equipment.

UNIDENTIFIED SPEAKER:

Did your task group use any of the computer data to see if equipment did make any difference on the probability of detection?

UNIDENTIFIED SPEAKER:

No, we didn't because not enough information was reported. Very general, transducer and serial number, for example. That is one thing that we would like to suggest next time, that if this experiment is repeated that much more definitive information be stored in the computer to allow this kind of analysis.

MR. SELNER:

Did you hear all that in the back?

Ward, you had a question.

UNIDENTIFIED SPEAKER:

I have a comment. One way of working equipment problems for unique applications is to identify it as a tool and supply it as a tool. And we will all use that.

MR. SELNER:

Ward's comment was that part of the solution to the problem of ultrasonic equipment is to identify it as a tool. I am not quite sure what the implication is there.

Are there any other comments or questions?

Yes, sir.

UNIDENTIFIED SPEAKER:

Could we initiate into this program some means of getting standardization among equipment such as the AC cord to all equipment? Each one of them comes out with

a separate type of plug. So, in our inventory we must stock at least 15 different types of AC cords just to fit individual units when one back-up cord for maintenance would be sufficient.

MR. SELNER:

This is a comment that can open up a real can of worms. I left this out for a reason. As you all know this is one of the topics that keeps getting kicked around, the one of standardization; not only equipment, for example, connectors, output probes, power cords, it includes nomenclature as well. I am sure that we would all agree -- I don't think we get any real dissenters other than probably the equipment manufacturers -- it would certainly be advantageous to all of us, both industry and government, if we had standardization both of equipment and nomenclature. And it is fairly obvious that the savings not only in time but the materials that you have to store in your laboratory, all the adapters for all these eddy current probes and different types of connectors on the ultrasonic probes, it creates problems.

It would be nice if we could get the equipment manufacturers to make their things fairly interchangeable and agree on terms.

Don.

UNIDENTIFIED SPEAKER:

I have not been going to ASTM meetings lately, but isn't there an ASTM committee on standarization? Does anyone in the room know?

UNIDENTIFIED SPEAKER:

Yes, Supposedly there will be an ASTM specification combining nomenclature and connectors for NDT equipment. Is that correct?

UNIDENTIFIED SPEAKER:

Would you repeat the answer?

UNIDENTIFIED SPEAKER:

What I said was that the committee that he is referring to, the ASTM committee on nondestructive testing, this committee has produced the documents on the standardized nomenclature. But as far as I know there is nothing on standardized power cords, connectors, equipment, so on.

MR. SELNER:

Bill Scruggs, you have a comment?

MR. SCRUGGS:

This is going back to Don's comment on the data that we have in the computer. There is a modest amount of information concerning equipment performance from all bases. We did check for instance linearity of both the sweep and vertical deflection on ultrasonic equipment. We ran step wedge shots and test developer strips on X-ray equipment and so forth. So, we do have this kind of information. It is semi-quantitative. We have serial numbers on the pieces of equipment used in all the tests that were performed. So, there is a fair amount of documentation in that area stored in the computer and will be available to, for instance, look at results compared to equipment performance.

MR. SELNER:

One other thing we might just throw out is that earlier this morning I was asked if there was any kind of a policy -- we talked about a repair policy would really be nice.

Going back one step further, do we have any kind of policy -- I am sure that we have a document that says we want a certain amount of transducers generating say five megahertz. Do we have, Bernie, in our system any means of quality control of the equipment coming in? I heard some comments about -- one of the problems is the poor quality of the eddy current, ultrasonic probe.

MR. BOISVERT:

In any complex organization -- and you can compare the Air Force to General Electric -- we have got 196 bases that need equipment throughout the world. Navy has a similar amount. So we are a big operation. Let's face it. We have got 20 major commands. Each has a little different mission, a little different application. So, recognize this as a problem. To answer the specific question, quality control of incoming material, we normally try to check the first model of a procurement buy. If we buy ultrasonic units, we check the first model of this.

We then depend upon the DCAS people, defense contracts, administration, DCASR, DCASA people to assure that the rest of the models are the same way. When we get them at Kelly, no, we don't check them. We don't even open the box. Normally, we send them out. In fact, many times we ask the manufacturer to deliver them to Wright-Patterson, or whatever Air Force Base.

MR CAUSTIN:

Do you, Kelly Air Force Base, give DCAS the test acceptance instructions that you want them to do, or is that left up to them?

MR. BOISVERT:

No. We ask the manufacturer to submit a proposed accetance test procedure. We ask him to submit to first, an article test where we go through and do all of the good things. Then the acceptance test procedures, and this we provide to the DCAS people.

Relative to Mil. Specs., great documents. Unfortunately, a Mil. Spec. requires a design engineer. And you equipment manufacturers have got staffs of 10-15 design engineers. I am sitting at Kelly with two people. We just cannot get into the design engineering phase. Let them do the design, and we will just buy it. That design they make so that Mr. Caustin, Mr. Hagemaier, so that everybody is using the same equipment. I am trying to use the same.

We are trying to use the same equipment that the air frame manufacturers, the engine manufacturers are using.

MR. SELNER:

I think we will close it there.

VI. RELIABILITY MEASUREMENT/MODELING

TASK GROUP LEADERS:

D. J. Hagemaier
S. Klima
W. D. Rummel

Mr. W.D. Rummel, Summary on Reliability Measurement and Modeling: In looking at the task of reliability modeling, we decided very early in the program that the best approach would be to determine that top 10 percent, select those, clone them, and get rid of all the other guys. That eliminates the problem. Now, in falling back on what can we do in the mean time, we took on some objectives. And the objectives were to define some approaches to modeling. There were two tasks in that, to try to determine what the critical characteristics were or are and also what the boundary conditions and assumptions are that we have to make in order to go forward with such an item. Now, in starting on that we looked at, first, what has been done in the past and what should we learn from that.

First of all, in the past programs we have tried to look at the capability of a technique to give us an output, normally in terms of flaw size, by minimizing all other variations, but specifically attempting to minimize the human factors.

Now, the area in which "Have Cracks" has changed that is we have variable human factors and human variables on the processes so that we have two things coming together which are changing what our output should be. So, we have a wider spread in the population. But we have emphasized in this case the human factors aspect. Now, if we go forward with that, what assumptions can we make, what lessons have we learned? First we say that the POD or probability of detection is a continuous function as a function of flaw size.

We see that a large crack and a slightly smaller crack as we home in on some threshold level at which the detection is going to decrease, as we approach that small crack size or drive in on it we don't expect to

RELIABILITY MEASUREMENT / MODELING

OBJECTIVES:

TO DEFINE APPROACHES TO MODELING

A. IDENTIFICATION OF CRITICAL ELEMENTS

B. IDENTIFICATION OF ASSUMPTIONS AND BOUNDARY CONDITIONS.

VIEWGRAPH 1

PAST PROGRAMS:

TO DETERMINE NDI CAPABILITIES AS A FUNCTION OF FLAW SIZE ---- MINIMIZE HUMAN FACTORS.

HAVE CRACKS:

TO DETERMINE NDI CAPABILITIES AS A FUNCTION OF FLAW SIZE ---- VARIABLE HUMAN FACTORS / HUMAN VARIABLE FACTORS.

VIEWGRAPH 2

see any dips or valleys in that. So, we think the range is not important in terms of our sampling. We simply see that as a continuous function. And that is very important as we go down the line.

The next thing is we assume a representative sampling of the population. There are things that we do in the statistical design of the experiment to assure that, but there are many parameters that play into this. So we are assuming that representative sampling. And there are some areas where we think we may have biased that.

The third item is that we assume that all observations are independent of each other so that one man looking at a single flaw is not affected by the next flaw that he sees, or his decision is not affected by the next flaw down the line. There are some reasons to argue that, but that has to be one of our assumptions.

We assume a constant calibration for whatever calibration will mean. And for purposes of this program and the past program we feel it is necessary to assume constancy of method. We don't at this point see a way to transfer X-ray data to eddy current data and so on.

And the final item in this is that we will assume that some level of false call-outs or false reporting is a condition of performing that inspection. Now, that is not an item we can vote on. It is something we have to accept as a condition of the inspection. Hopefully, we choose an inspection method which has the proper leeway or boundary condition so that that value is very low. But that is one of the things we do have to live with.

Now, if we go and look for common denominators in all of these things we see that the probability of detection is some function of the signal to noise of the operation. That includes both the signal to noise of the inspection output or all the process steps that we are going through and the manner in which the human responds to that signal level.

Some of the functional elements that contribute to that, or the important functional elements that contribute to that are the method selection, the human

RELIABILITY MEASUREMENT / MODELING

ASSUMPTIONS

1. P.O.D. A CONTINUOUS FUNCTION OF FLAW SIZE
2. REPRESENTATIVE SAMPLING OF THE POPULATION
3. OBSERVATIONS INDEPENDENT OF EACH OTHER
4. CONSTANT CALIBRATION
5. CONSTANT METHOD
6. SOME LEVEL OF FALSE REPORTS IS A CONDITION OF INSPECTION.

VIEWGRAPH 3

COMMON DENOMINATORS

P.O.D. = F (S/N)

S/N INSPECTION OUTPUT , S/N HUMAN RESPONSE TO OUTPUT

FUNCTION ELEMENTS

METHOD SELECTION

HUMAN FACTORS

EQUIPMENT – STANDARDS

TEST OBJECT

VIEWGRAPH 4

factors element, the equipment and standards -- and we did combine those -- and the test object or the item that we are trying to interrogate. Now, in terms of method selection I think we were not redundant with other groups. We said that the flaw was an important swinger in type, geometry, size. And that was with our length, depth and width, or closure being part of the width, location and orientation.

And the test object itself in which we were interrogating to find the flaw was important in material shape, geometry, access, and so on. The environment is important to selection of the method.

Now these factors are also important in some of the other areas.

If we go to the human factors -- and we talked a lot about human factors -- we see the two primary things in being the human response to the stimuli of the inspection and the confidence of the man that is making that decision in that stimuli or his decisiveness, his responsibility, and his risk assessment. And that includes both risk to him by making the decision and the resultant risk if he makes the wrong decision to a system or someone else. Now, with that we got back into experience. We think experience is important. We think the quality of that experience may be the thing that will reduce the scatter. We think that is extremely important.

The training is important, but the quality of the training is important. The supervision is important. Certainly the quality of the supervision is important. His motivation -- he needs a method of self-check of his work. He needs a self-assessment of work quality. He needs some objective peer assessment of that work quality and certainly needs an objective management assessment of that work quality.

Those factors at this time seem to be totally missing from our systems.

Then there are, of course, man/machine interface equipment problems that have to do with dexterity and

RELIABILITY MEASUREMENT / MODELING

METHOD SELECTION

FLAW — TYPE
GEOMETRY
SIZE (LENGTH, DEPTH, WIDTH)
LOCATION
ORIENTATION

TEST OBJECT — MATERIAL
SHAPE
GEOMETRY
ACCESS

ENVIRONMENT

VIEWGRAPH 5

HUMAN FACTORS

HUMAN RESPONSE TO INSPECTION STIMULI

CONFIDENCE (DECISIVENESS, RESPONSIBILITY, RISK)

EXPERIENCE (QUALITY)

TRAINING (QUALITY)

SUPERVISION (QUALITY)

MOTIVATION — SELF ASSESSMENT OF WORK QUALITY
OBJECTIVE PEER ASSESSMENT
OBJECTIVE MANAGEMENT ASSESSMENT

MAN/MACHINE INTERACTION — EQUIPMENT
AUTOMATION

ENVIRONMENT

VIEWGRAPH 6

so on. There are man/machine interfaces that can be worked with respect to the output stimuli response. One of the things we saw is in going to automation we changed some of those demands on the man. But we also greatly improved the signal-to-noise or the margin that he has to slice to make the right decision.

Finally, his environment will be important in the decisions that he makes.

The test object is important in that what we are looking for in the test object is an equivalent inspection stimuli to translate data or to model from one situation to another. We think that that can be done by the proper approach to the calibration or the calibration and setup, taking into account some of the things that we talked about in material geometry and so on.

An important item comes into the area of concentration. We talked a little bit yesterday about hot spots. If a man has a task that he thinks is attainable, then his approach to that task is certainly better. So, his ultimate response will be better. We think that may be an area where we are getting benefit in looking at hot spot areas.

Equipment, we left that to Group IV. We didn't try to solve all problems for everyone.

We looked at the questions and added some of our own. In terms of the hotness of the issues we tried to list them in priority. First on the list is false reporting. Everyone is interested in false reports. That is the highest interest issue. The majority of folks thought it was not just merely an economic factor but there was some other information intrinsic to false reporting. But no one was able to put rationale or an approach to how we should handle that beyond tracking it and reporting it at this time. We think that that can be handled in one of the down line studies.

The majority of the opinions said that we indeed ought to penalize a man for false reports in the same way that college entrance exams are penalizing. But, once

RELIABILITY MEASUREMENT/MODELING

EQUIPMENT

TASK GROUP V

VIEWGRAPH 7

QUESTIONS AND ISSUES

1. FALSE REPORTS - HIGHEST INTEREST ISSUE

   MAJORITY - NOT SOLELY ECONOMIC FACTOR
   REPORT
   NO RATIONALE

   MINORITY - PENALIZE FOR FALSE REPORTS
   NO RATIONALE

2. 90/95 CRITERIA

   MAJORITY - YES
   LOWER SAMPLING MORE FREQUENT INSPECTIONS.

VIEWGRAPH 8

again, no rationale for that other than that is something that has been done and is recognized as one technique in trying to condition the human response.

The second issue was the 90/95 criteria that Tom Cooper has been talking about. Is it necessary? Our majority opinion says, yes, that that is a necessary condition, that if we go to a lower sampling the end result will be that we must make a more frequent inspection if we want to maintain the same confidence. So, we are not really saving money by backing off in the front end.

The third item was: Should the inspector know he is being tested. We had a majority "no" opinion. At the same time that majority recognized or was of the opinion that probably isn't possible in any of the tests that we do or any of the testing that we do down line. We had a minority opinion that we should let the man know.

And the rationale behind that is we should not play games with the man.

In terms of the reliability transfer -- that is one of the questions, is it a feasible approach -- we think that it is. And the model that we are proposing here, or this approach is one way of doing it.

A final item is: Who uses the data and can get rid of some of the information, hone it to a specific user group? At this point everyone is interested and everyone wants to cut it a little differently. So, it looks like we need to record all of the boundary conditions and assumptions along with all of the quantitative information that we take at this time, because we don't have rationale to really read it out.

Finally, we took on the challenge of windows. We see there are three programs or three actions that need to be taken.

The first has to do with the human factors area. We found this is probably a convenient approach since the Air Force also has organizations, or is organized along this line. We need to study the man/machine interfaces in both physical and mental output as a function of the signal-to-noise stimuli.

RELIABILITY MEASUREMENT/MODELING

3. INSPECTOR KNOWLEDGE OF TEST?
   MAJORITY — NO, PROBABLY NOT POSSIBLE
   MINORITY — NO, DON'T PLAY GAMES
4. RELIABILITY TRANSFER?
   MODEL APPROACH PROPOSED
5. WHO USES DATA
   EVERYONE — HOW TO CUT?
   RECORD ALL BOUNDARY CONDITIONS AND ASSUMPTIONS.

VIEWGRAPH 9

WINDOWS

HUMAN FACTORS

S/N

- MAN/MACHINE, PHYSICAL/MENTAL
- PATTERN RECOGNITION

EQUIPMENT

S/N

- STIMULUS LEVEL
- PATTERN

VALIDATE MODELING APPROACH

S/N TRANSFER FUNCTION/TEST OBJECT SHAPE

VIEWGRAPH 10

And the second area is one which is a little harder to put into perspective. We are all familiar with the signal-to-noise voltmeter response. But the second part of that, important to NDT, is the pattern recognition part. So, that human factor study needs to look at both the signal-to-noise from the standpoint of the thing we are traditionally looking at in the electronics area plus the pattern recognition factor that goes along with it. There are established methods that the human factors folks measure that can address themselves to this problem. So maybe we are beginning to talk the language by taking this approach.

The second area, in the equipment level we think we need to hone in and emphasize the stimulus that the instrument is putting out in both level -- and that has to do with signal-to-noise -- and the pattern, because both of those items fall into it. So as we drive in on equipment improvements, those are the factors we are really interested in improving in equipment. All the other things can make them specialized and so on but they don't do this job. They are not really helping us out in terms of working a reliability problem.

Finally, we think we need to validate a modeling approach. We think that should be very simple. In the first case to look at this signal to noise, the stimulus, as a method of assessing transfer function, to start out with a simple case such as transferring the test object shape from the flat to the curved or the flat to a complex. This method, to test it in one simple case and then beyond that build. So, we think that these are valid things that can be done at this point.

Questions?

UNIDENTIFIED SPEAKER:

I would like to elaborate a little bit on the comments about the attention factor or the Hawthorn effect, whatever you want to call it, when people are tested and know they are being tested. I think it has been shown repeatedly in almost every psychological test that people do better if they get attention. Just

recognize their activity and they will always do better. I think this result is somehow in the "Have Crack-Will Travel" results. And we should look at the results of "Have Cracks" as being an upper limit. It could be much worse.

MR. RUMMEL:

There are some comments that we thought this was one area in which "Have Cracks" did a good job in having a long-term series of inspections so that whatever group --- vigilance would occur as the guy got used to the situation should have been worked in this. We are not together on whether that is a driving factor at this point or not.

UNIDENTIFIED SPEAKER:

Did you look at the false report statistics that came out of the "Have Cracks"? And, if you did, can you make some statement about what the probability of false reports were and what that means?

MR. RUMMEL:

On false reports, one of the computer dumps that we asked for and just got this morning was: What is the false call frequency for the upper 10 percent performers versus the lower 10 percent performers? What it looks like to me is we have about equivalent situations in this case. And that is different than other programs have come up with. I would attribute that to the greater sampling of the population. But we looked at it for just one test specimen.

MR. CAUSTIN:

Were the false reports screened by the supervisor like you would normally do, or this was just raw data:

MR. RUMMEL:

No. In addition to that I think that in treating -- well, the first of all this dump on the false reports had not been cleansed in terms of constructive data. So

there may be some error there. Secondly, the outliers have not been cleansed so that in one case the man found more false call-outs than were possible decisions.

MR. CAUSTIN:

My point, though, is it was not cleansed like you normally do, so the data in the computer can mislead you. And as a result, I don't agree that you should penalize for false reports. You are going to get that when you are working in high sensitivities. You have got to screen them. And then you have got to recognize the data.

MR. RUMMEL:

Okay. For those of you that did not hear, Ed does not agree that we should penalize for false reports. I, personally, don't either. Part of the rationale for that is at high or critical performance areas where we have a lower signal-to-noise, a false call incidence is going to increase. And that has to be part of the risk that we take when we perform that inspection. It has to be part of the experiment.

Joe.

UNIDENTIFIED SPEAKER:

The discussion several people have made about the Hawthorne effect or whatever, I have always been of the opinion that if you are going to test people it is best to let them know because if you don't do that you won't know what effect it has on the final results. Maybe halfway through a test you will get people who will figure it out. And then all of a sudden your test has changed. You don't know when it changed because they may figure it out in the middle. You don't know if some people figure it out and some don't. All of a sudden you might have two distributions right in the middle.

A second comment on the 90/95, I think the committee said that you should do it because if you don't do it in the front you are going to have to do it someplace

down the line. That does not to me address the question of whether 95 is realistic at any place. Whether really we should just cut away the 95 all through the program. And I think the answer I heard was that if we don't put the 95 on in the beginning, we are going to have to put it on in the back someplace. I am not sure that the 95 is really necessary.

MR. RUMMEL:

That incidentally was the only rationale we came up with for keeping it. It is one of those things that everybody feels we should, but is a little soft in terms of rationale.

UNIDENTIFIED SPEAKER:

With respect to not penalizing for false calls what do you do when the probability of a false call is higher than the probability of detection? Is that a potential?

MR. BOISVERT:

Very much so.

MR. RUMMEL:

That is a potential. That says the signal to noise is very unfavorable. And you are expecting because you are in serious trouble. You know the inspection is not going to be very reliable but you are willing to take the results of what you get.

UNIDENTIFIED SPEAKER:

Is it kind of like the crying wolf?

MR. RUMMEL:

It can be crying wolf. But when you get into that situation you have to go into it with your eyes open. And you are usually in trouble to start out with. The risk has been made and you will take it consciously or unconsciously.

UNIDENTIFIED SPEAKER:

I was one of those who attended one of your sessions. What I think some of us tried to get across was not penalize false reports period, but penalize those who have repetitious false reports just because of their tendency to play it safe.

MR. RUMMEL:

Okay. The gentleman has a statement that we should penalize false reports in a long-term management sense based on the inability of a guy to make a decision or his decisiveness as opposed to the capability of the test. My opinion is that you can't do that because you don't have the right measurement feedback in your own system.

MR. CAUSTIN:

Well, it depends on what your outcome was.

MR. RUMMEL:

Right.

UNIDENTIFIED SPEAKER:

Is the data in a format that will allow you to call out if you went to a base, for example, and were there for a month or so to look at the results as a function of time to see whether it peaks early and decreases or comes out as a --

MR. RUMMEL:

The question is will the data base allow us to look at performance capability as a function of time in this case calendar date to try to put to bed the Hawthorn effect.

Is that reasonably the question? Okay.

MR. BOISVERT:

The answer is yes.

MR. CAUSTIN:

Apparently you had a vote in this No. 3 item, could you do this job without an inspector knowing he is being tested. Apparently there was a vote. I say you can and it has been demonstrated that you can. I was just wondering of those people who voted how many have tried it.

MR. RUMMEL:

The question is on the inspector's knowledge of test, how many have tried it. And in that group probably less than 10 percent have tried it.

UNIDENTIFIED SPEAKER:

There was an industrial test --

MR. RUMMEL:

The question is: We had a gentleman in session two of this task group who had conducted an industrial test. There was an industrial test done in which a part was put through the line so all the other parts looked alike.

MR. BOISVERT:

We still need the question repeated.

UNIDENTIFIED SPEAKER:

It was a statement that in the session two we have talked about this. I had made the comment that at our factory not to test the inspector but just to prove to the engineers a point about fracture critical parts, that you don't play games with inspectors, that you identify the parts as fracture critical so the people know they have got a hot part that they have got to pay more attention to. To prove that to ourselves we took a

series of fatigue cracked samples, about 28 of them that had a population of about 27 cracks -- not in all the samples, but like some samples had three cracks, some had none -- and we just put them with a fab order, sent them down to the shoes for inspection. They found none of the cracks. We simply cleaned the specimens, put a critical parts tag on them, sent them back. And they found 26 out of 27.

UNIDENTIFIED SPEAKER:

Is that a different procedure?

UNIDENTIFIED SPEAKER:

Same procedure, same people, same process.

MR. CAUSTIN:

In our shop it is a different proceduure for fracture critical parts.

UNIDENTIFIED SPEAKER:

Yes, but we had not started fracture critical, All we did was stick on this red tag that said these are fracture critical parts and the same inspector, same process, everything the same. The only thing that was different was the tag.

UNIDENTIFIED SPEAKER:

In the case of false calls on Specimen D which later turns out through destructive testing to have no cracks, was that a matter of signal-to-noise problem or was that a matter of misinterpretation of strong signals from other reflectors?

MR. RUMMEL:

It is the same. That is the same.

UNIDENTIFIED SPEAKER:

I recognize that is the same. But in a sense misinterpretation of a signal that has a stong signal-to-noise

ratio is an error in interpretation and more of a human factor problem than it is of an equipment-type related problem.

MR. RUMMEL:

So it is a pattern recognition problem.

UNIDENTIFIED SPEAKER:

Were false calls included in the calculation of the curves that were presented Tuesday?

MR. RUMMEL:

The answer to that is no. The false calls are reported in tabular form, but they are not part of the curve calculation. No one knows how to handle it yet that I am aware of.

UNIDENTIFIED SPEAKER:

Then you are really loading the curve?

MR. RUMMEL:

Yes.

UNIDENTIFIED SPEAKER:

It seems that in this case you have the benefit of destructive testing after the test. Was the data analyzed for what they would expect to have found without destructive testing versus what they would have found, what they did find when they did destructive test the parts? Well, in other words, you are doing nondestructive testing. Your nondestructive testing criteria are established in some way, usually on the basis of some probability from some destructive testing.

So there is one way of establishing this. Now, these parts were all destructively tested after the series of tests. And you had the benefit of knowing whether or not the indication was of a certain magnitude and a

certain location where you wouldn't always have that had you not destructively tested the parts after the test series.

UNDENTIFIED SPEAKER:

Well, no secondary backup procedure was used whereas if they were arranged in normal Air Force procedure --

UNIDENTIFIED SPEAKER:

In other words, most of the time in your testing you may reject a part or accept a part from an indication that you assume is either false or inaccurate and it may or may not be.

MR. RUMMEL:

I think I understand the question.

We sometimes will reject since our ability to specify what we are going to see and what is acceptable in a penetrant area may not be precise. And I think that is different from the programs that we are trying to measure. That almost gets into the lawyer area.

Other comments, Bernie?

MR. BOISVERT:

Yes. Hey, we can continue this all day. I would like to, We are running way behind time.

MR. CAUSTIN:

I am getting the impression that people feel false calls are bad. But take another look at it. That is a measure of conservatism of the process. And it is more deleterious to the object to miss something that you should find. It is a measure of conservatism. Don't look at it as a negative.

MR. RUMMEL:

One additional thing I thought was interesting in that respect was one fellow said that false calls were good because they keep the operator alert.

MR. BOISVERT:

We are running way behind time. How about if we do this on reliability measurement and modeling, we will delay additional comments until the very end of the meeting. Those of us that want to continue this discussion -- and I am one -- we will remain here after we officially adjourn. Right now what we would like to do is take about a five-minute relief break, okay.

VII. FRACTURE MECHANICS/NDI INTERRELATIONSHIPS

TASK GROUP LEADERS:

W. L. Castner
E. L. Caustin
M. A. Owen

MR. BOISVERT:

The next group concerns the interface or the interrelationship between the structural engineer, the guy doing the data damage tolerance analysis and the NDI. To help us in this area I think we have got perhaps the outstanding group, Bud Castner from NASA, Johnson Space Center, Ed Caustin, and one of the guys that really is honchoing the whole thing, Mark Owen out of our structural engineering group at Wright-Patterson.

Mark.

MR. M. A. OWEN, Summary on Fracture Mechanics/NDI Interrelationship: As Bernie mentioned we were looking at some of the interrelationships between this area of fracture mechanics and NDI. I am happy to report that we did find that there are some interrelationships. On behalf of Bud and Ed, I would like to thank those that participated in our task group. We had some good participation, good discussions. But I feel a little bit like a saying that a friend of mine has: We came, we saw, and two out of three is not bad.

We did, however, reach some concensus. I think in order to present the things that we were able to conclude we will just proceed into the items that the three of us, the three task leaders, decided that were consensus of all the people that met with our specific group.

One that came through very clearly is in the area of communication. And it was broken down into three different aspects of communication. That communication I am talking about is communicating problems and lessons learned. One is that the Air Force has a considerable amount of information in the fracture mechanics area specifically that is not being done in a

FRACTURE MECHANICS/NDI INTERRELATIONSHIP

FRACTURE MECHANICS/NDI

CONCENSUS ITEMS

- COMMUNICATION IMPROVEMENT REQUIRED - LESSONS LEARNED, ETC.
  - AF INFO TO ALL SERVICES
  - FRACTURE MECHANICS AND NDI
  - INDUSTRY EXPERIENCE IN NDI

VIEWGRAPH 1

- FRACTURE MECHANICS UNCERTAINTIES
  - MATERIALS DATA BASE
  - ENGINE ENVIRONMENT IMPACT
- "HOT SPOT" INSP. RELIABILITY SHOULD BE BETTER THAN "HAVE CRACKS WILL TRAVEL"
  - PROCEDURES MORE SPECIFIC
  - NOT ROUTINE
  - BEST INSPECTORS

VIEWGRAPH 2

damage tolerance assessment of old airplanes that is not really being communicated, not a conscientious effort being made to communicate to all other services, to industry. So, we need to make an effort on the Air Force side to improve that kind of communication. The NDI people are probably doing a little better job on the Air Force side by having meetings like this. The communication between fracture mechanics people and NDI people needs to be improved. Each has their own unique set of problems. And there is a lot of misunderstanding between those two sets of groups about what those unique problems are.

I think those of us involved in fracture mechanics often ask the impossible of the NDI people. I think sometimes the NDI people ask the impossible of the fracture mechanics people. They want to know exactly what they are to look for, exactly where it is going to be, exactly what it is going to look like when they see it. We need to improve the overall communication and process there.

One thing that came out during the course of our session is that there is a lot of industry experience in NDI, programs such as the B-1, lessons that have been learned there on correct procedures to use in doing NDI that are really not being transitioned into the Air Force services.

So, that communication needs to be improved.

The next concensus that we were able to reach is that we have seen a lot of statistics that show that there are uncertainties in NDI. There are also some uncertainties in fracture mechanics as well. One large group of uncertainties is in the entire materials data base for fracture mechanics, especially in some of the older -- as we began to analyze some of the older airplanes with not so recent materials where we didn't look at damage tolerance type properties. And consequently no data were generated on those materials.

A big area that was mentioned is as the Air Force moves in to look at flight damage tolerance criteria to the

engines, is that whole aspect of the engine environment and the impact that that is going to have on predicted lives and how do we really design with all those uncertainties that have to do with temperature, time, creep, all the other things that go into the engine and its structure.

We also reached the conclusion after some amount of debate, I guess, that these statistics that we see here and that came from the "Have Cracks-Will Travel" we can do better than that in specific hot spot inspections. We think when procedures are specifically set to analyze or look at one specific area of structure that is decreed to be a hot spot and especially critical, if it is not a routine type of inspection that people go in there knowing the criticality of that specific area and that if we somehow decide who the best inspectors are and then pick those best inspectors to do that specific inspection, then the reliability numbers that you would see for those specific hot spots would be better than what we see in the "Have Cracks" effort.

Some more concensus items. With respect to NDI reliability demonstration programs we about concluded that those type of programs would not be very practical or indeed very helpful for routine inspection on aircraft. There are two reasons I guess that we see that. This is specifically with respect to implementing those ten or fifteen, the latest Air Force criteria. Number one, in design of new aircraft we are not depending on in general the fleet inspections, the in-service inspections to protect the airplanes. We are treating a lot of parts as non-inspectable and trying to design in enough damage tolerance so that we don't have to perform a lot of inspections.

Another aspect to that, not practical for routine inspections, and I forgot what it is right now. I will come back to it.

However, as opposed to routine inspections, there are a lot of hot spot inspections that we are in the process of having to do on some of our older airplanes, notably the T-38 as was cited yesterday. And I guess we all agreed that in addition to having the best inspectors

FRACTURE MECHANICS / NDI INTERRELATIONSHIP

- NDI DEMONSTRATIONS
  - NOT TOO PRACTICAL FOR ROUTINE INSPECTIONS
  - DESIRABLE FOR "HOT SPOT"
- TRADE-OFF STUDIES REQUIRED
  - MORE FREQUENT INSPECTIONS
  - MULTIPLE TECHNIQUES
- SCREENING SAMPLES VS ACTUAL STRUCTURE NEEDS RESOLUTION
- ROUTINE NDI CAN'T BE RELIED ON TO PROTECT FLIGHT SAFETY FOR GENERALIZED A/C CRACKING.

VIEWGRAPH 3

ADDITIONAL QUESTIONS

- IS 90/95 REALISTIC?
  - NO, FOR ROUTINE
  - REASONABLE GOAL FOR F/C
- ARE PRODUCTION DEMOS APPLICABLE TO ASSEMBLED A/C?
  - NO STUDY AVAILABLE

VIEWGRAPH 4

and having it not routine and spelling out special procedures that it also would be desirable to have a demo program for those hot spot inspections to improve the overall confidence that we have a higher reliability of finding the things that we need to find. It was pointed out, however, that it may not be -- hot spots come up all of a sudden sometimes. And you don't have a lot of time to put together a demo program before you go to the inspections. So that is kind of the other side of the coin.

We also concluded that looking at these reliability statistics that came out of "Have Craks," we concluded apparently what the reliability group concluded that there needs to be some trade-off studies run with those reliability results. This specifically came up in the area when we discussed the 90-percent probability with 95-percent confidence level criteria.

There are a lot of other ways to achieve that same level of reliability. A couple of those other ways are with more frequent inspections or with multiple inspection techniques. And it would be an interesting course of study to use these statistics that came out of "Have Cracks" and put all those numbers together. That is a requirement.

The other one that was not too practical for routine inspections, NDI demonstration is that personnel keep getting moved around quite a bit. In the Air Force we don't keep the same inspector all the time and continue the update process. Sometimes the inspections are kind of done all over the territory. Now, when we say NDI demo, that is not the same thing as certification. I hope everyone understands that.

The other area that we concensus was in the area of the presentation that was made with respect to the screening samples. That whole area of screening samples, the reliability that came out of screening samples versus the reliability that comes out of actual structure, that whole area has got to be resolved. The ultrasonic inspection showed the same trend, but there was no correlation at all with the eddy current inspections.

So that has to be resolved because that has pretty dramatic implications even to an NDI demo program.

Then, we finally came to the conclusion that on the basis of these "Have Cracks" numbers that routine NDI cannot be relied on to protect flight safety for generalized aircraft cracking. And the example that we cited there was the KC-135 where cracks could be any place in the wing or cover. these statistics tell us that we could not protect the flight safety of that airplane by normal routine inspections. We have to come up with the other means to protect flight safety at this point in time.

Now, of course, there were some other questions that we didn't really reach a concensus on. One that several people discussed was: is 90/95 realistic? I guess on the basis of these statistics we concluded that it is not realistic for routine inspections if that is what these statistics are representative of. Maybe it is not realistic or even necessary is the other thing we concluded. However, it is a reasonable goal for fracture critical parts. For parts that the flight safety of the airplane depends on not having a crack in 90/95 is a reasonable goal. We used the term "reasonable goal," which doesn't say that if you come up with 85 percent probability and 95 percent confidence level that that is bad. 90/95 is a reasonable goal.

And another question that there was considerable interest in is: Are the production NDI demonstration programs that have been run, like on the B-1 and A-10 and others, are they really applicable to assembled aircraft? The only thing we could conclude about that is that we don't even know of a study that answers that question. It is an interesting question, however. So, on the basis of all that concensus and the unanswered questions we came up with this list of recommended studies. One is in the area of reliability trade-offs. The other is a study with respect to production NDI demonstration applicability. We asked ourselves the question how would Air Force-type people, the same field level type people have done with a production NDI demo-type program, what reliability would have come out of that. And on the other hand, how

RECOMMENDED STUDIES

- RELIABILITY TRADE-OFFS
  - INSPECTION FREQUENCIES
  - MULTIPLE TECHNIQUES
- PRODUCTION DEMO APPLICABILITY
- OPTIMIZE T.O. PROCEDURES FOR F/C PARTS
- RISK ANALYSIS STUDIES (B-52, KC-135, ETC.)

VIEWGRAPH 5

CONCLUSIONS

- NEW DESIGNS SHOULD HELP NDI PROBLEM
- "HOT SPOTS" WILL CONTINUE
- IN-SERVICE NDI NEEDS TO BE IMPROVED

--- HOW WOULD OTHER A/C DISCIPLINES FARE UNDER THE SAME SCRUTINY???

VIEWGRAPH 6

would production people have done with the "Have Cracks" type of study?

We did not know the answer to that. So that would be an interesting course of study.

Another concern that came up was: Have the inspection procedures been detailed and optimized enough for fracture critical parts?

In other words, the procedures that were identified in the "Have Cracks" Program, were they really optimized if you were inspecting fracture critical parts? There might be some way to further optimize those procedures. For instance, one point that came up was if you cleaned bolt holes prior to eddy current inspection.

Finally we concluded that with respect to one of the last questions we were asked to look into; that is, methodologies for cranking all these results together, inspection of reliability models, flaw population models. There are some techniques to do that, and those are in the form of risk analysis. There have been such studies run on the B-52, the KC-135, and others. What we are suggesting is it would be an interesting course of study to take the "Have Cracks" numbers and crank that into a risk analysis to see what type of sensitivities and economic answers one might come up with.

Conclusions: We think new damage tolerance designs are going to alleviate somewhat this NDI Problem. We are going to be shooting for less field inspections to protect safety of flight. We are going to design in safety of flight from the beginning throughout the life of the airplane.

However, we don't expect all the hot spots are going to go away. We are still stuck with some of the same design concepts that we used to use. So all the NDI people are going to have to pack up their equipment as soon as we get a new fleet of damage tolerance designed aircraft in the field.

However, I don't know how anybody could look at the "Have Cracks" data and not conclude that the in-service

NDI needs to be improved. On the other hand we asked ourselves one last question that we would like to have you ask yourself. And that is: How would the other aircraft disciplines besides NDI fare under the same kind of scrutiny that has been given the NDI program at this point in time. I don't quite know the answer to that question, but it is worth thinking about.

That is all I have. I would be happy to entertain any questions you may have or any comments, additions, or corrections that anybody who particpated in our group would like to bring up at this time.

VIII. DATA ANALYSIS

TASK GROUP LEADERS:

D. E. Pettit
J. A. Moyzis
R. R. Wagner

Mr. J. A. Moyzis, Summary on Data Analysis: Okay. We are starting off with something we have heard about already. Maybe we have had more discussion on this than the whole subject merits in this conference. But let me just go over these points that we have come to, the conclusions we have come to. The first one that we looked at was false calls and analytic treatment in the reliability data. Really what I would like to say that is not very important but there are so many issues that are really important in the data that we have collected so far that unless costs are a prime consideration -- and we have heard some of that in the production environment -- but unless costs become an overriding consideration, maybe this topic is not as important as a number of other topics.

Now, as far as how you analytically treat -- one suggestion arose during the discussion that one way of handling the data is to try to correlate the percentage of false calls that an individual generated to his performance overall, whether he was a good inspector overall or a bad inspector overall or whether he was a high false call rate meant or correlated or was related to the fact that he had a good performance on small flaw sizes, which might indicate that he is looking for everything and he is calling the small flaws but he is also calling things that aren't there.

But as far as analytically folding it into the curve, there was not any concensus at all to do that.

The third bullet there is that the feeling was that if somebody wants to do an analytic treatment -- and as I guess I have already said, nobody that we heard in our discussions in all three discussions was in favor of folding this data in analytically. And I seem to hear from another group that there was some rumbling about that. But we did not hear it in our group.

DATA ANALYSIS

FALSE CALLS

- NOT IMPORTANT UNLESS COSTS ARE PRIME CONSIDERATION.
- CORRELATE TO INSPECTOR PERFORMANCE
- ANALYTICAL TREATMENT NEEDS MATHEMATICAL RIGOR
- CONCENSUS
  - NO ANALYTICAL TREATMENT
  - REPORT FOR INFORMATION

VIEWGRAPH 1

DATA SCATTER

- LOW 95% CONFIDENCE LEVELS INHERENT IN SCATTER
- REDUCTION OF SCATTER
  - PLOT VS DIFFERENT PARAMETER
  - ALL DATA FROM SAME DISTRIBUTION

VIEWGRAPH 2

If there is such a desire to do that, there better be some mathematically rigorous analytic treatment that everbody will buy rather than the kind of thing I think college professors do on multiple choice questions: Well, I will arbitrarily take two points off for a wrong answer and get some sort of a score. So, rather than any kind of a hokey analytic scheme, if you are going to do it, it better be something that has a mathematical rigor.

The concensus overall on this false call was that don't analytically fold it into the data. And that was uniform. I was surprised. I really expected and I have heard from other people in the past personally that you should. And in this group it was uniform, don't. But there was a very definite feeling like, don't ignore the data. You want to have this kind of data available so you know who the people are who are giving you the false calls. Maybe that is a cry of wolf. But if you find a guy who cries wolf every once in a while, he is also finding small defects, too. Now, that is really all we came up with on false calls.

Now, an important thing that came up in our discussions was this idea of our 95-percent confidence levels. The point was raised, and I think is a very good one, there is a lot of scatter in the data. and when you look at the scatter in the data one thing right away, you are not going to get a good 90/95 percent confidence level just by collecting more data. So, you somehow say, "Well, the 95-percent confidence level is low because you don't have a lot of sample points." And I have said that in the past myself. But when you look at the data and it has that much scatter, if you collected 10 times more data that has that amount of scatter, maybe your 95 will shift a little but it is not really going to get up into the 90 percent level and answer the question of what crack level can we find things to 90/95. So, that comes out that just collecting more data of this kind is not going to help.

The second thing is: What do you do about the scatter? Why is there scatter? One thing is that it may just be inherent in the data. You may just have that kind of thing inherently. But a couple of suggestions of how we

might investigate whether that scatter can be reduced is to look -- we do plot versus crack length. Is the crack length the meaningful parameter? Is there another parameter that we could plot the reliability against that might reduce the scatter? That could be one way.

Another one is the question of any time you do a least squares fit or any kind of a fit, if you look in the statistics book there are all the conditions that the data is supposed to satisfy so that the least-square fit would really mean something. In a linear regression you get the thing that this formula is good for if you have a distribution, a normal distribution around a mean at every "X" value, and that normal distribution is the same for every "X" value, that the deviation from the mean is the same all the way through. Is that true for this data? I think we have got enough data where we can start looking at some of this. We can pick a crack length and take a look at how the data is scattered and take a look at whether it is uniform along the way. And also the question: Is all the data that we are using from the same distribution.

Are there a uniform set of inspectors? Are they poor inspectors? Are they good inspectors? So we end up with at any crack size, not a normal distribution but maybe a bi-normal or tri-normal or multi-normal. Maybe we could reduce the scatter by breaking it up a little. The point is, I think, overall, that unless you can reduce the scatter, the question we would like to ask and we historically started out to ask about 90/95 was: Where is that magic number that I can guarantee I can find all cracks above. We can't find that collective data this way. And that was something that came up.

The next story that came up -- and it is a one liner -- is that there has to be a great deal of recognition in the fact that statistics does not give you cause and effect, it gives you relationships. I wish I would have said that. But somebody did. When you see a relationship you have got to be very careful about what that means. That does not mean that because the eyeglasses and reliabilty somehow show up with some sort of a relationship, that doesn't mean that because you take a

DATA ANALYSIS

STATISTICS GIVE RELATIONSHIPS,

NOT CAUSE AND EFFECT

VIEWGRAPH 3

MULTIVARIANT ANALYSIS

- TEST INTERACTION OF VARIABLES
- ARE ALL IMPORTANT PARAMETERS AVAILABLE?

DATA ANALYSIS - DEPENDENT ON USE OF RELIABILITY RESULTS

- 90/95
- COST-RISK ANALYSIS
- NDE/FM INTERFACE
- FACILITY COMPARISON

VIEWGRAPH 4

normal operator and poke him in the eye so he has to wear glasses, he will get better. That kind of a thing has to be said. It is just a one liner, and it has to go along with everything else we see here.

Another point that was brought up was with the amount of data we have could possible start to do some multi-variant analyses with the data. Now, I was given some key phrases: Aid analysis, which I know something about: progrit, which I know nothing about. There was a number of them that were suggested. But here is an opportunity with the number of parameters we have, instead of plotting and anlyzing things as a function of one parameter maybe we can go into a multi-parameter analysis. One is to test the interaction of the variables, we can maybe see whether some of these relationships are really meaningful. Maybe it is correlated or related to some third thing that we should bring in. And also maybe a multivariant analysis would bring out the fact of whether you have all the important parameters, you have collected all the important parameters. There was a definite feeling by a number of people -- you can collect parameters forever.

But there are possibilities that the psychological makeup, that nebulous thing that a guy carries on inside himself may be the most important thing. It has nothing to do with his age or glasses or hair color or whatever. Maybe a multi-variant analysis cannot answer that. What important parameters do you leave out? Maybe it will point to the fact that there are parameters in there that you have not paid attention to. We can't tell you what they are, but maybe you should go looking for them.

Now, another point that was brought out in the data analysis is that the type of data analysis you do is very dependent on what you are going to use the reliability results for. Now, historically I think that the reliability data that has been collected -- it started out sort of an NDI fracture mechanics relationship. But since I have been in on the thing anyway it said 90/95 question where is the largest crack you can find.

When you ask that question, you collect the data in the way that we have been collecting it. You might try to fit with a curve where the 95-percent confidence level crosses the 90 level. Now you can say I know where it is and try to draw a smooth curve. Maybe we are wrong in doing that. There are a lot of different functions that your reliability data might want to assess; 90/95, cost/risk analysis, NDI/fracture mechanics, facility comparison. Somebody brought up the point that maybe you should be giving a standard statistical question to the data. You can make the hypothesis that the probability of detection by the depots is equal to the probability of detection in the field. You can test that hypothesis. That is a different kind of treatment of the data. You can do it at any single crack length.

So, if you are going to analyze the data, if you are going to use a certain model, you have to keep in mind what you want to do with it. That is where you bring the statistician in. You say: This is the kind of question I want to answer, how should I collect data, what should I do so that I have a possibility of answering that question.

The recommendations that we were able to glean out of this was that there is not a lot of reason to go on and start collecting more data until we fully analyze the present data that is available. That takes the Air Force off the hook for more money. If you analyze the data that is available that will allow you perhaps to define thee questions that you want the further data to answer. You have got a certain amount of data now, and you can milk it for all it is worth and try to come up with those questions you would like to have answered and see which ones are. If you find some that are important that are not answered, it gives you a motivation to go out and fill a gap of that part of the data. You can direct the kind of data that you are going to get.

If you have a very specific question that you would like to answer that not only would allow you to see the kind of data you want to collect, but beforehand you could lay out the models. This is how I am going to analyze the data when I finally get it. I am going to

DATA ANALYSIS

RECOMMENDATIONS

- FULLY ANALYZE PRESENT DATA BEFORE FURTHER DATA COLLECTION
  - DEFINE QUESTION(S) DATA SHOULD ANSWER
  - DEFINE ANALYSIS MODEL
  - DEFINE EXPERIMENT TO ELUCIDATE CAUSE AND EFFECT
  - DATA SHOULD BE AMENABLE TO DIFFERENT ANALYSIS METHODS

VIEWGRAPH 5

- CONCENSUS NEEDED ON DEMO DATA HANDLING
- GLOSSARY OF RELIABILITY DEFINITIONS FOR NDE

VIEWGRAPH 6

do it this way because this is the kind of question I want to answer. It will also allow you to design the experiment to elucidate cause and effect, in other words, to try to get closer to that cause and effect rather than coming up with some relationship.

How are you to design the experiment so that you can have a stronger feel that there really was a link between Parameter A and Parameter B? And something I think that maybe as we were putting it together we looked at this is when you do this you would like to have 20-20 hindsight at the beginning. It would be nice when you do this maybe to have some idea of if I just asked a question, I lay a model, it may turn out when I am done, two or three or four years down the line, that the world is changing. Can I try to guess what the world is changing. Can I try to guess what that change may be so that when I do collect the data I am not hung with the fact that I have data that can only be analyzed one way and will only answer one kind of question and it turns out that this is not the question we are interested in. That is an impossible thing to do in any kind of rigor. But maybe when you're trying to do that kind of a look ahead, you should at least try.

A separate recommendation was that there should be some concensus on the handling of data in demonstration programs. I think the demonstration programs up to now have been a range type of analysis. And partly I think that is done because of cost. The 90/95 costs a lot of money.

So, you isolate four range sizes or so. Is there some way that maybe demo data could be handled where we could get away from that kind of expense?

Now, there is an ASNT document that has been floating around for a long time and may eventually be published. I would undoubtedly think that when it finally gets out the people will say what the heck is this all about. I can't buy that at all.

And finally, a suggestion was made that a glossary of definitions would be nice so we all know what we are talking about. What is a confidence level? I think if

we get about five or ten people in a room, we should have between two and five different definitions and a big argument. I think that the ASNT document tries some of that. I don't know how extensive that would be. Some of the discussions we do have when we rant and rave and disagree with others is because we are really talking about different things.

That is all I have to say.

UNIDENTIFIED SPEAKER:

This ties into your last thing about definitions. I think one thing that everybody recognizes is that as your noise goes up, false calls go up. When you start talking about a false call, well, is ultrasonic scatter a false call or is it noise? I think we need a definition of what noise is and how that ties into false calls.

MR. MOYZIS:

Okay. A false call to me is anything off of nothing or off of something that is not a crack.

MR. CAUSTIN:

Some of the data that I looked at on this test that was run from your "Have Cracks-Will Travel Program" indicated that it was not run with fracture mechanics in mind as far as the -36 manual is intended. So, your interface with fracture mechanics, you are really stretching it when you are talking about 90/95 because you have already put the inspector in a bad position. You did not give him instructions in the calibration. In other words, those disciplines that you use for a fracture critical. And also the high number of false calls -- and I guess you must have gotten an enormous number of them because everyone seems so concerned about it -- tells me that there also must have been something wrong with the techniques used. False calls are another look at the techniques.

For example, did you clean up those holes before you looked at them with eddy current. Normally, in the

teardown in our world we do that to reduce the number of false calls. So, those kind of things tell me that, hey, there is still question about how it was run before you take a look at that data across the board to make a lot of answers.

MR. MOYZIS:

Okay. I don't know the number of false calls that were made. I don't think this data was collected for fracture mechanics particularly. It was collected to see how well are we doing in the field. We have gotten into a lot of defining things on how we'll do on 90/95.

UNIDENTIFIED SPEAKER:

There were a lot of false calls. There were a few people, Ed, that did have a preponderance of false calls. But they were the exception rather than the rule. I would say generally it was fairly low.

MR. BOISVERT:

I tried to point --- that we put this program just like we were doing four years ago. We have improved somewhat in the program. But this is what we are doing in the field. Now you make the point: Do we clean up. No, no. We don't have time to clean up in a maintenance environment unless it is a real serious condition. Normally, we go out and inspect. If it is very critical, then we do go in and inspect.

MR. CAUSTIN:

If you shoot for 90/95 that is critical.

MR. BOISVERT:

The original intent was to find out where are we today. That was four years ago. Now we are coming up with this 90/95. It is a good question, but the original intent was to find out where we are today.

I would like possibly to recognize everybody, all of the task group leaders one time because I think they

have done an outstanding job. They have given me enough work to do. I would like a big hand for these task group leaders, please.

This concludes the meeting.

Section VI
LUNCHEON ADDRESS SUMMARY

A summary of the luncheon address, "The Role of Inspections in the Maintenance of Aircraft Safety" by Mr. C. F. Tiffany, USAF Air Systems Division, Wright-Patterson Air Force Base, Ohio, is provided to exhibit the technical challenges for NDI. No prepared text was available for this summary but the viewgraph copies were. The commentary is therefore derived from recollections of the talk combined with information from the visual aids. All percentage values are estimated from diagrams. Copies of the viewgraphs are included at the end of this Section.

Topic Outline

- Some Aircraft Accident Statistics
- Primary Causes
- Some Basic Aspects of Structural Failures
- Past USAF Approach to Aircraft Safety - Shortcomings of Approach
- Current Approach
- Some Examples of Current Inspection Problems
- Summary

USAF Aircraft Accidents and Mishaps

Of a total of 3,824 occurences over a 15-year period, 1,664 were attributed to logistics involving airframe, engines and accessories. The remainder were attributed to operations, miscellaneous, weather and unknown causes.

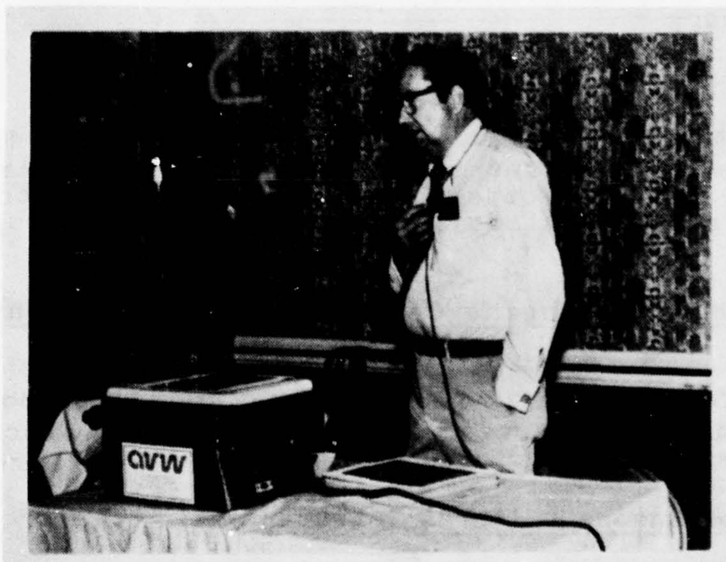
Distribution of Engine Caused Aircraft Accidents and Mishaps

Engine failure causes had an approximate breakdown of; 40% primary structure, 40% pumps, controls, etc., and 20% sub-system structure.

Causes of Engine Failures (Structural)

A structural failure cause breakdown for engines shows approximate proportions of; 27% material defects, manufacturing or assembly flaws and design deficiencies,

MR. W. H. LEWIS INTRODUCING THE LUNCHEON SPEAKER,
MR. C. F. TIFFANY



THE LUNCHEON SPEAKER, MR. C. F. TIFFANY

27% fatigue, 12% stress rupure, 10% excessive creep, 10% control malfunction, 8% corrosion, and 6% foreign object damage.

Crack Initiation/Growth and Failure Mechanisms (Structural)

Of 1226 major cracking/failure incidents over a 21-month period, approximately 60% were fatigue caused, 35% attributed to corrosion, 4% of overload, and 1% to unknown causes. Another study of 64 incidents attributes failure causes to; 65% corrosion, 24% fatigue, 10% overload, and 1% unknown causes.

Cracking and Failure Origins

A study of 64 major cracking/failure problems on military aircraft over a 6-month period yielded the following approximate proportion of causes; 60% pre-existing material and fabrication quality deficiencies, 12% service-induced corrosion pits and scratches, 16% design deficiencies such as poor design details with sharp corners, and 12% unknown causes.

Some Basic Aspects

- Aircraft often contain pre-existing flaws; nicks, scratches, cracks, tears, etc.
- Flaws grow in size with time (flight hours).
- Part failure occurs when the flaw reaches critical size.
- The time to failure (life) depends on the initial flaw size and the crack growth rate.
  - Factors which influence the initial flaw size are: material process, manufacturing process, quality control and inspection.
  - Factors which influence crack growth rates are: usage severity, stress levels, environment and material.
- Aircraft safety can be achieved by:
  - A design and maintenance plan which ensures crack detection and repair before cracks reach critical sizes (the safe crack growth approach) or

- A design which can tolerate a single part or member failure without causing loss of aircraft (i.e. the fail-safe approach).

o Prior to 1970, the Military required neither approach.

o The Fail-Safe approach has generally been used for commercial aircraft.

The Pre-1969/70 Approach

o Design and Analysis
  - "Safe-life" fatigue design and analysis for safety and durability required that a predicted mean life for a failure occurrence distribution be established. a scatter factor for four (4) is then applied to conservatively estimate the design life, i.e., the design life is one-fourth (1/4) of the predicted mean life.
  - The mean life predictions are based on unflawed lab specimen data and Miner's rule of cumulative damage.
  - The scatter factor is assumed to account for the effect of initial quality (flaws) and the environment and variations in material properties.
  - No crack growth analysis was required.

o Testing
  - Fatigue testing (for safety and durability) involved block spectrum loading.
    - The test duration was four (4) lifetimes.
    - The full-scale test article was a production aircraft.
    - There was no schedule requirement.
    - The acceptance criterion was, "no failure in four (4) lifetimes".
    - There was no damage tolerance testing required.

o Force Management
  - The assumed "safe-life" of the force was 1/4 of the test life.
  - Maintenance actions (inspections and modifications) were based on the test time occurrence of failure (when in the 4 lifetimes) divided by four (4).

- The maintenance times were adjusted by fleet tracking records.
- It was assumed that the 1/4 test life limit and scheduled inspections would allow safe operation.

Shortcomings of the Pre-1969/70 Approach

- o It did not preclude the improper use of high-strength, flaw-sensitive materials.
  - Small critical cracks in these materials can jeopardize safety and/or result in expensive inspection programs.
- o It did not always inhibit the use of excessively high stress levels.
- o Early catastrophic failure can negate determination of actual economical operational life.
- o In-service inspections will not protect uninspectable structure.
- o Safety of monolithic structures is necessarily assured by using fatigue test results and a scatter factor of four (4).
- o It did not preclude the use of stress corrosion sensitive materials.
- o It lacked accountability of load ordering effects.
- o It was often deficient in critical area identification.
- o It lacked visibility of crack growth characteristics necessary for an economical and effective force management program.
- o It often resulted in late test results, and thus costly retrofits.

Current MIL-STD-1530A Approach

- o The "Safe-life" approach has been abandoned and safety and durability requirements decoupled.
- o Safety-Aircraft will be designed to be damage tolerant by either;
  - Fail-safe or
  - Safe Crack Growth criteria.
- o Durability - Aircraft will be designed such that the economic life is greater than the required design life.

- Fail Safe Design - The structure is designed to contain a single member failure without loss of the aircraft. Limitations of this approach are:
  - Early detection of member failure is required.
  - It is generally heavier than the safe crack growth approach.
  - Fail-safety deteriorates with onset of adjacent member cracking.
- Safe Crack Growth Design - The structure is designed (and inspected) so that the maximum expected initial damage will not grow to critical size during service use. Limitations to this approach are that safety is dependent on:
  - A fracture control program which is necessary to ensure that no initial flaws greater than the size assumed in design will escape detection.
  - An individual aircraft tracking program with recorded service history is required.
  - Fracture critical areas must be accurately identified.

Some Examples of Current USAF Inspection Problems

These problems include detection of:

- Onset of general area cracking in fail-safe cargo/transport/tanker aircaft.
- Single member failure in nonflight or ground evident fail-safe structures.
- Inner tab (hidden splice element) cracking in shiplap wing planks and stringer cracking in skin and stringer wings.
- Small crack detection at fastener holes without fastener removal.
- Very small crack detection at fastener holes with fasteners removed.
- Very shallow surface and small internal cracks at specific locations in gas turbine engine parts.

Concluding Remarks

- Aircraft safety is vitally dependent on reliable in-service inspections.
  - The inspection problem is generally most difficult with slow crack growth designs.

- The inspection problem is not severe on older aircraft.

o Required detection capabilities vary with specific applications, however, they are typically as follows for airframes:
  - Fastener holes with fastener removed; 0.05" or less corner flaws.
  - Fastener holes with fastener in-place; 0.10" corner flaws.
  - Inner layer and/or interior stringers; 0.20" to 0.50" through-the-thickness flaws.
  - At free edges; 0.05" corner flaws for hi-performance engines:
  - Surface flaws; 0.01" or less in depth.
  - Internal flaws; 0.02" or less in diameter.

THE ROLE OF INSPECTIONS

IN

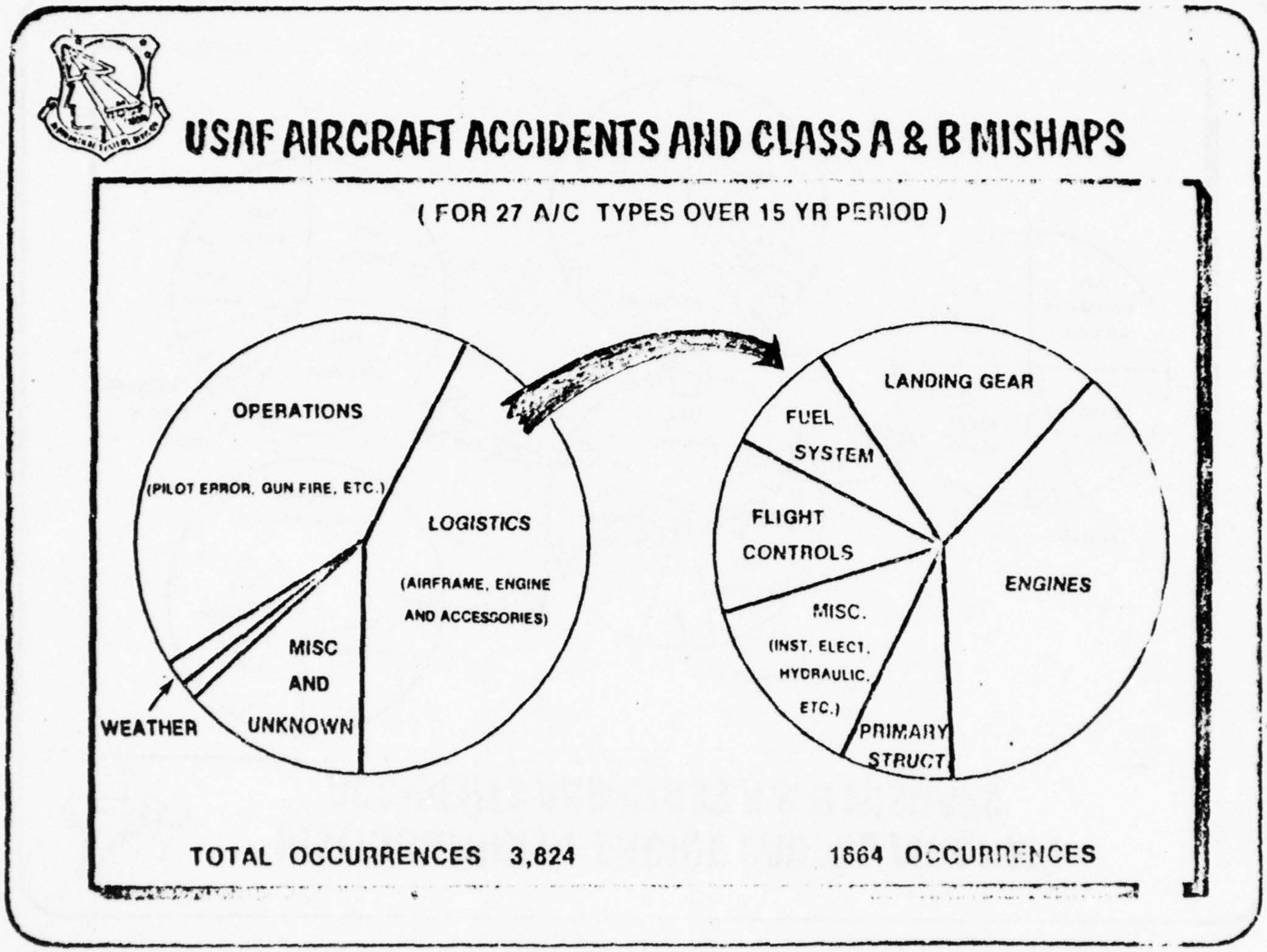
THE MAINTENANCE OF AIRCRAFT SAFETY

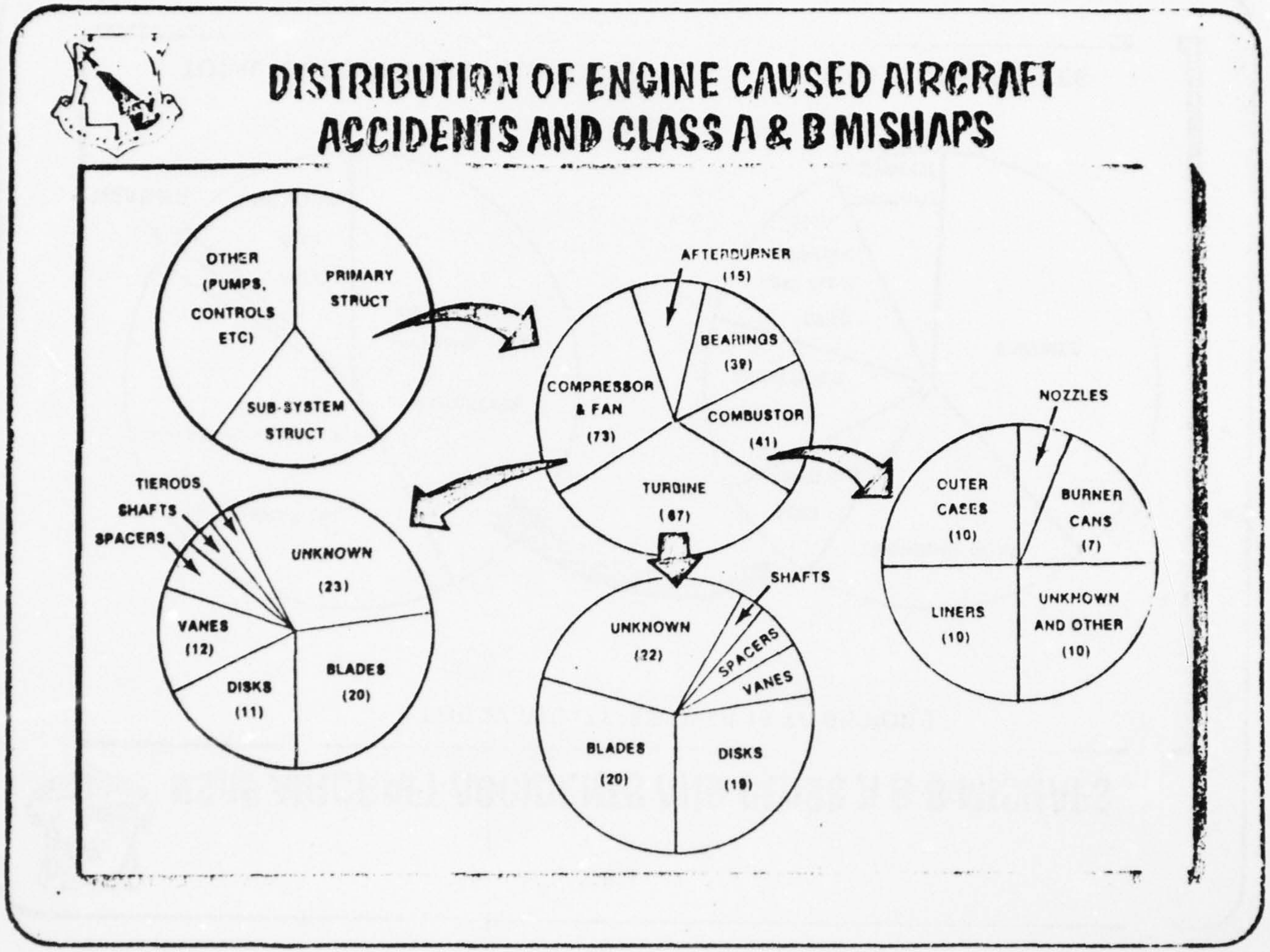
BY

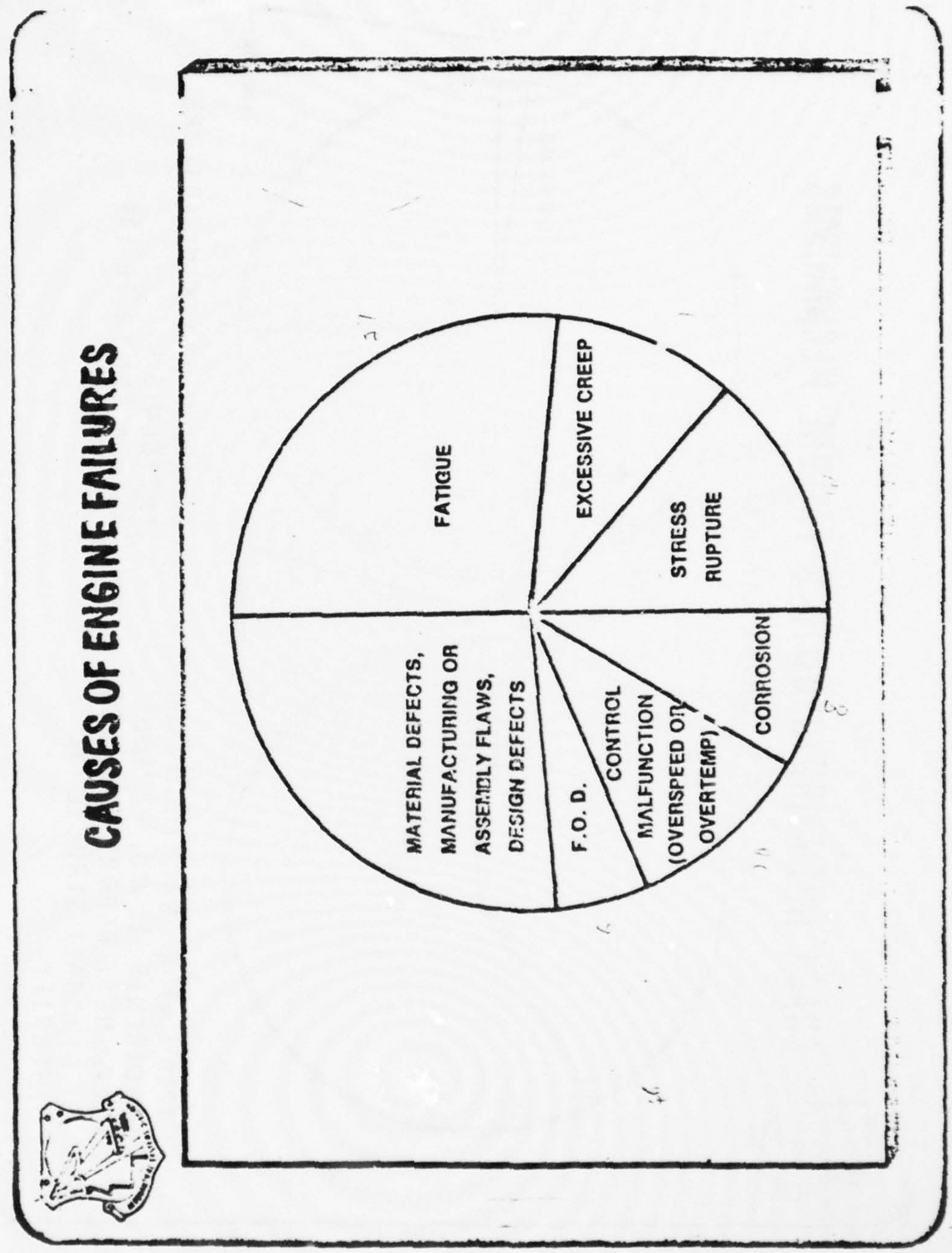
C.F. TIFFANY ASD/EN

OUTLINE

- SOME AIRCRAFT ACCIDENT STATISTICS
- PRIMARY CAUSES
- SOME BASIS ASPECTS OF STRUCTURAL FAILURES
- PAST USAF APPROACH TO AIRCRAFT SAFETY
  - SHORTCOMINGS OF APPROACH
- CURRENT APPROACH
- SOME EXAMPLES OF CURRENT INSPECTION PROBLEMS
- SUMMARY


USAF AIRCRAFT ACCIDENTS AND CLASS A & B MISHAPS
(FOR 27 A/C TYPES OVER 15 YR PERIOD)
OPERATIONS
(PILOT ERROR, GUN FIRE, ETC.)
LOGISTICS
(AIRFRAME, ENGINE AND ACCESSORIES)
MISC AND UNKNOWN
WEATHER
LANDING GEAR
FUEL SYSTEM
FLIGHT CONTROLS
MISC.
(INST, ELECT, HYDRAULIC, ETC.)
PRIMARY STRUCT
ENGINES
TOTAL OCCURRENCES 3,824
1664 OCCURRENCES

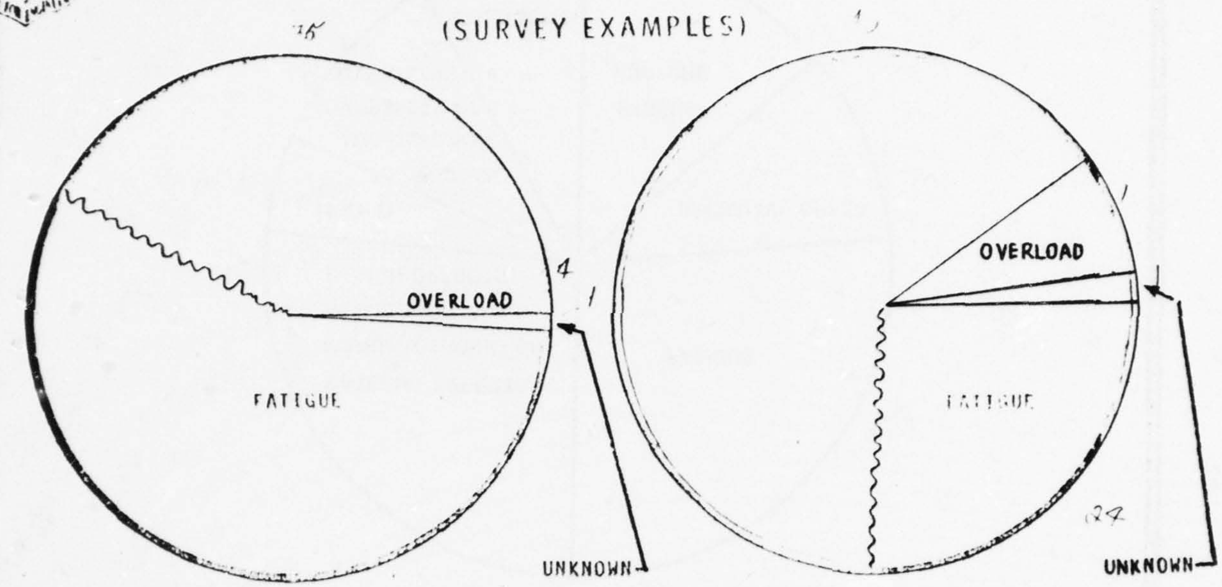

DISTRIBUTION OF ENGINE CAUSED AIRCRAFT ACCIDENTS AND CLASS A & B MISHAPS
OTHER (PUMPS, CONTROLS ETC)
PRIMARY STRUCT
SUB-SYSTEM STRUCT
AFTERBURNER (15)
BEARINGS (39)
COMPRESSOR & FAN (73)
COMBUSTOR (41)
TURBINE (67)
NOZZLES
OUTER CASES (10)
BURNER CANS (7)
LINERS (10)
UNKNOWN AND OTHER (10)
TIERODS
SHAFTS
SPACERS
UNKNOWN (23)
VANES (12)
DISKS (11)
BLADES (20)
SHAFTS
UNKNOWN (22)
SPACERS
VANES
BLADES (20)
DISKS (19)



CAUSES OF ENGINE FAILURES
FATIGUE
EXCESSIVE CREEP
STRESS RUPTURE
CORROSION
CONTROL MALFUNCTION (OVERSPEED OR OVERTEMP)
F. O. D.
MATERIAL DEFECTS, MANUFACTURING OR ASSEMBLY FLAWS, DESIGN DEFECTS

CRACK INITIATION/GROWTH & FAILURE MECHANISMS

(SURVEY EXAMPLES)

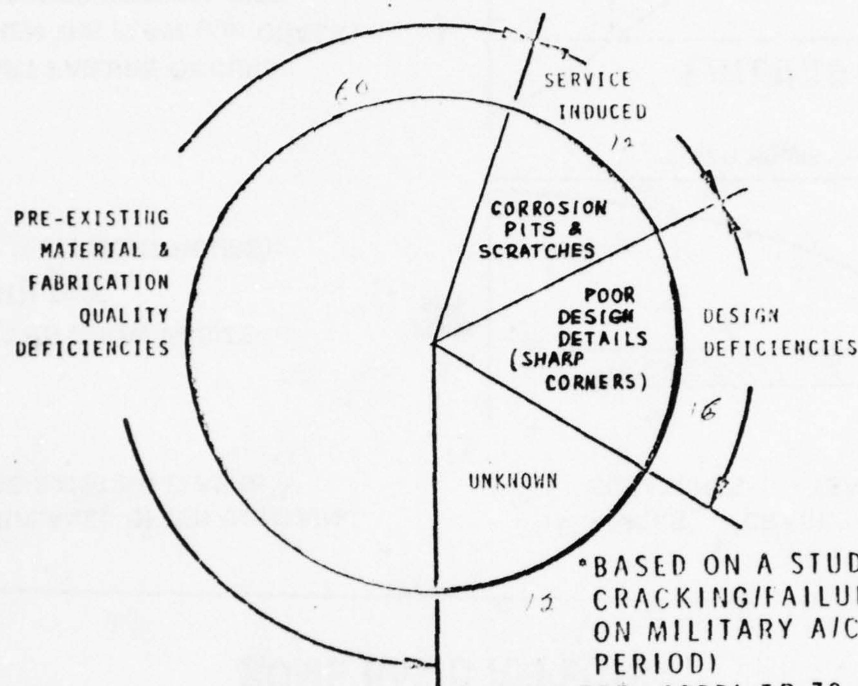


1226 MAJOR CRACKING/FAILURE INCIDENTS (21 MO. PERIOD)
REF: USAF REPORT ON STUDY OF AIRCRAFT STRUCTURAL INTEGRITY

64 MAJOR CRACKING/FAILURE INCIDENTS
REF: AFFDL TR-70-149

CRACKING & FAILURE ORIGINS*

(SURVEY EXAMPLE)



*BASED ON A STUDY OF 64 MAJOR CRACKING/FAILURE PROBLEMS ON MILITARY A/C (6 MONTH PERIOD)
REF. AFFDL TR 70-149

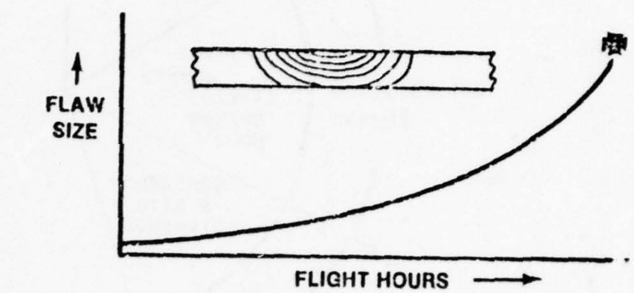
SOME BASIC ASPECTS

- AIRPLANES OFTEN CONTAIN PRE-EXISTING FLAWS:

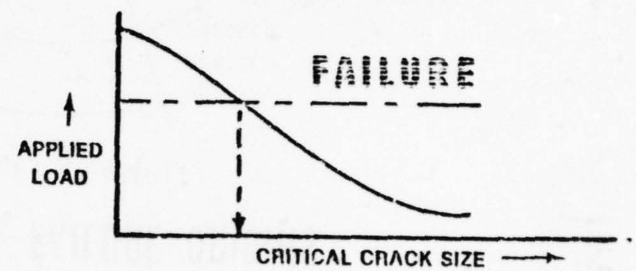
  - KNICKS - CRACKS - ETC.
  - SCRATCHES - TEARS

- FLAWS GROW IN SIZE WITH TIME

  (I.e. FLIGHT HOURS):

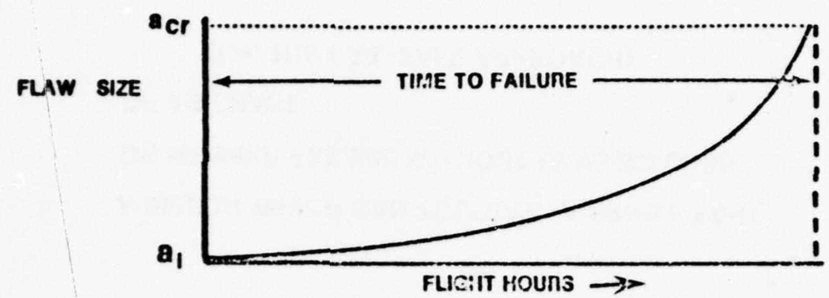


- PART FAILURE OCCURS WHEN THE FLAW (I.e. CRACK) REACHES CRITICAL SIZE:



BASIC ASPECTS (CONT'D)

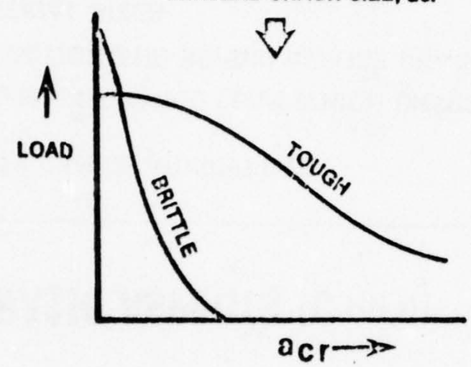
- TIME TO FAILURE (OR LIFE) IS THUS DEPENDENT ON:



INITIAL FLAW SIZE, a_I

- MAT'L PROCESS
- MFG. PROCESS
- QUALITY CONTROL
- INSPECTION

CRITICAL CRACK SIZE, a_{cr}



CRACK GROWTH RATE

- USAGE SEVERITY
- STRESS LEVELS
- ENVIRONMENT
- MATERIAL

BASIC ASPECTS (Cont'd)

- AIRCRAFT SAFETY CAN BE ACHIEVED BY:
  - A DESIGN & MAINTENANCE PLAN WHICH ENSURES CRACK DETECTION AND REPAIR BEFORE CRACKS REACH CRITICAL SIZES

    (I.e. THE SAFE CRACK GROWTH APPROACH)

    OR

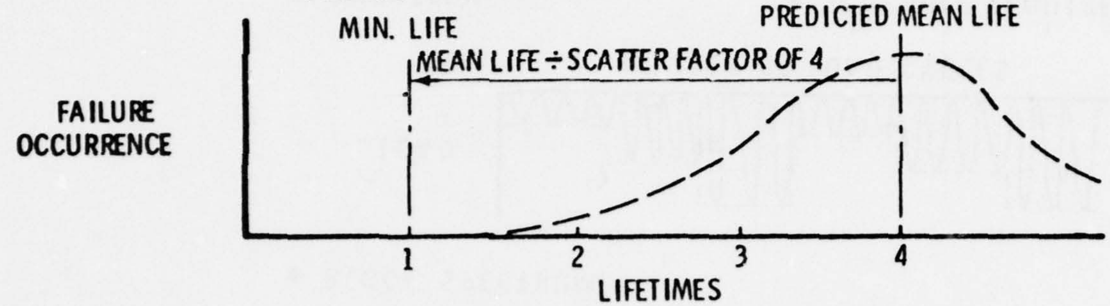
  - A DESIGN WHICH CAN TOLERATE A SINGLE PART OR MEMBER FAILURE WITHOUT CAUSING LOSS OF AIRCRAFT

    (I.e. THE FAIL-SAFE APPROACH)

- PRIOR TO 1970 THE MILITARY REQUIRED NEITHER APPROACH
- FAIL-SAFE APPROACH HAS GENERALLY BEEN USED FOR COMMERCIAL AIRCRAFT

THE PRE 1969/70 APPROACH

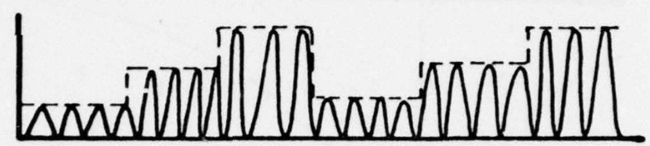
- DESIGN AND ANALYSIS:
  - "SAFE-LIFE" FATIGUE DESIGN & ANALYSIS FOR SAFETY & DURABILITY



- MEAN LIFE PREDICTION.
  - BASED ON UNFLAWED LAB SPECIMEN DATA
  - MINER'S RULE CUMULATIVE DAMAGE ANALYSIS
- SCATTER FACTOR ASSUMED TO ACCOUNT FOR:
  - EFFECT OF INITIAL QUALITY (FLAWS)
  - EFFECT OF ENVIRONMENT
  - EFFECT OF VARIATIONS IN MATERIAL PROPERTIES
- NO CRACK GROWTH ANALYSIS REQUIREMENT

THE PRE 1969/70 APPROACH (Cont'd)

- TESTING
  - FATIGUE TESTING (SAFETY & DURABILITY)
    - BLOCK SPECTRUM:



- DURATION:
  4 - LIFETIMES
- TEST ARTICLE:
  PROD. AIRCRAFT
- SCHEDULE REQUIREMENT:
  NONE
- ACCEPTANCE CRITERIA:
  NO FAILURE IN 4 LIFETIMES

- DAMAGE TOLERANCE TESTING
  - NONE REQUIRED

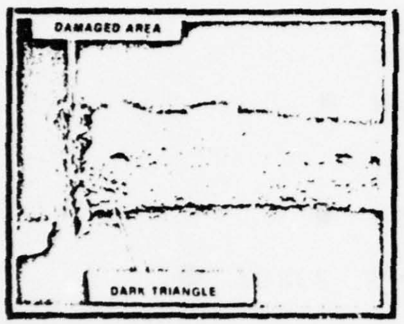
THE PRE 1969/70 APPROACH (Cont'd)

- FORCE MANAGEMENT:
  - ASSUMED "SAFE-LIFE" OF FORCE = 1/4 OF TEST LIFE
  - MAINTENANCE ACTIONS (INSPECTIONS & MODS) BASED ON TESTOCCURRENCE(WHEN) DIVIDED BY 4
  - MAINTENANCE TIMES ADJUSTED BASED ON TRACKING DATA
  - ASSUMED 1/4 TEST LIFE LIMIT AND INSPECTIONS PROTECT SAFETY

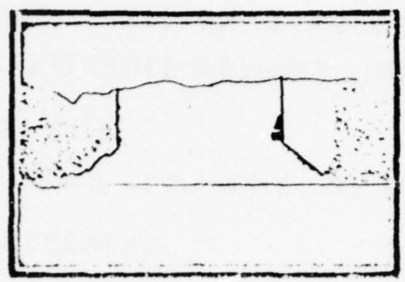
SHORTCOMINGS OF THE PRE 1969/70 APPROACH

- IT DID NOT PRECLUDE IMPROPER USE OF HIGH STRENGTH FLAW SENSITIVE MATERIALS:

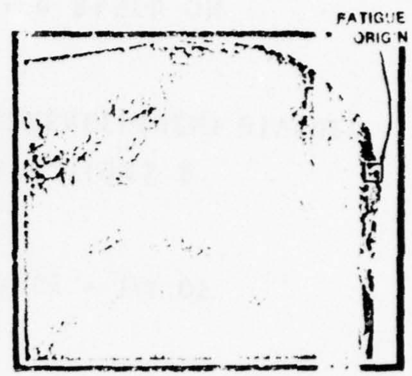
EXAMPLES



F-5 WING FAILURE ORIGIN



KC-135 28'' WING CRACK ORIGIN

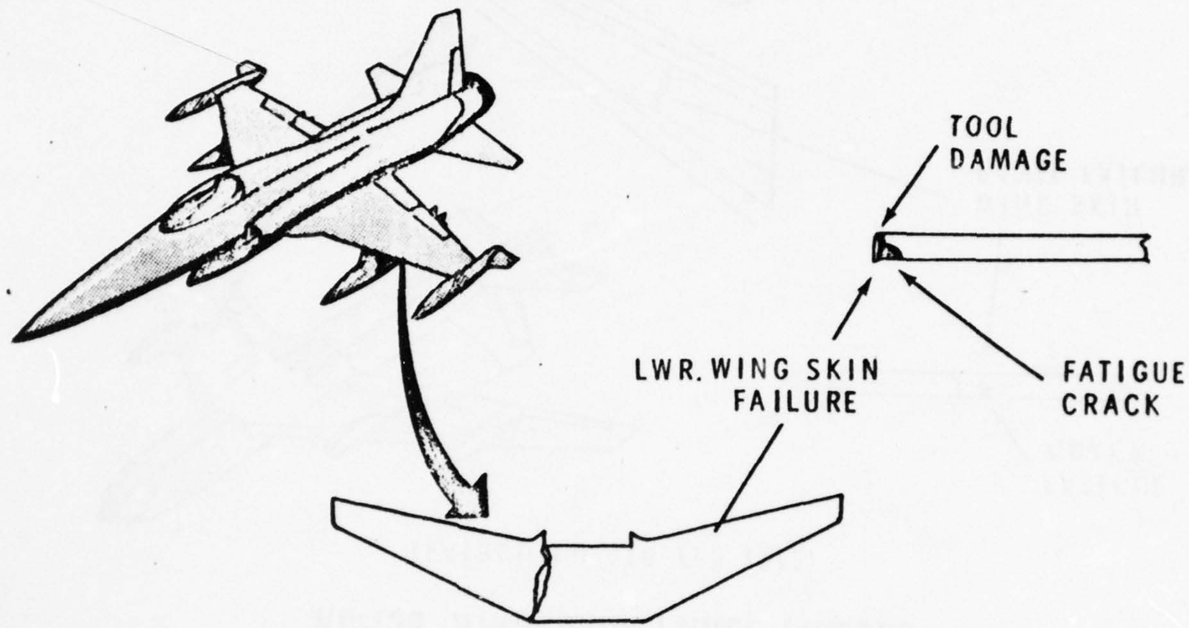


F-4 WING FAILURE O[illegible]N

- SMALL CRITICAL CRACKS CAN JEOPARDIZE SAFETY AND/OR RESULT IN EXPENSIVE INSPECTION PROGRAMS

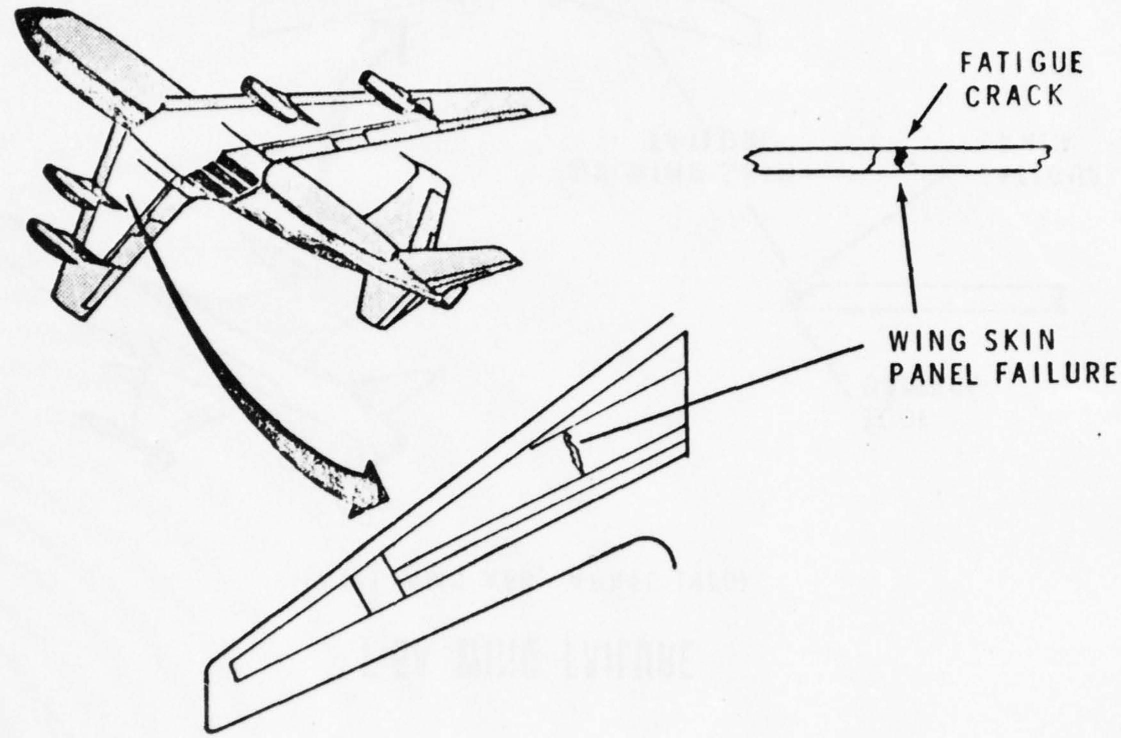
F-5A WING FAILURE

(WILLIAMS AFB, APRIL 1970)



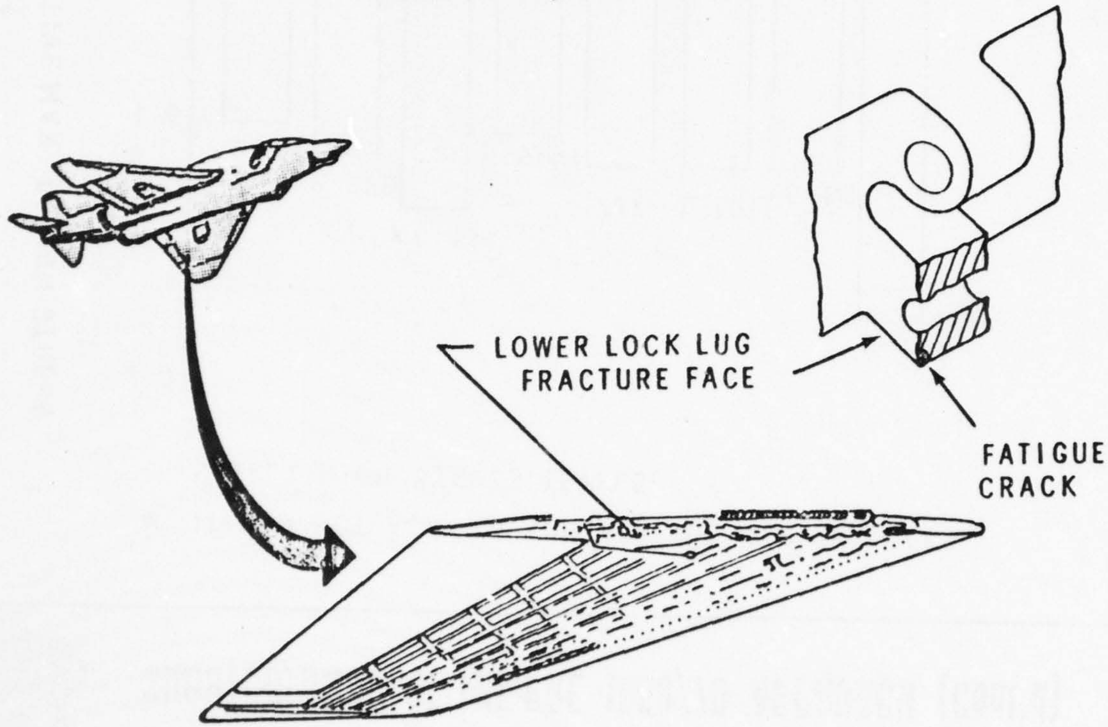
KC-135 WING SKIN PANEL FAILURE

(FAIRCHILD AFB, FEB 1972)



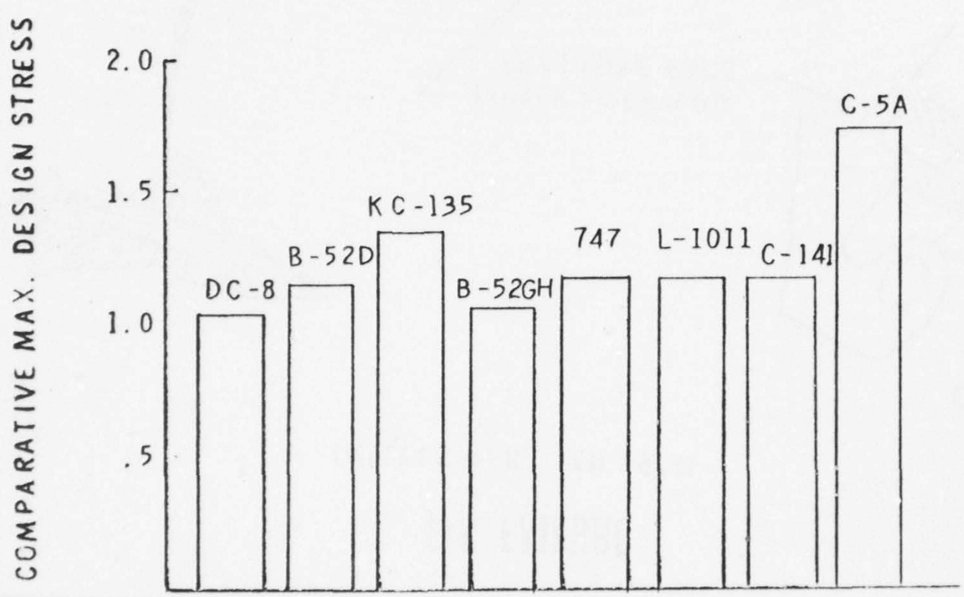
F-4 FAILURE

(NELLIS AFB, JAN 1973)



SHORTCOMINGS OF THE PRE 1969/70 APPROACH (Cont'd)

- IT DID NOT ALWAYS INHIBIT THE USE OF EXCESSIVELY HIGH STRESS LEVELS:



AD-A068 223 LOCKHEED-GEORGIA CO MARIETTA F/G 1/3
PROCEEDINGS FROM THE GOVERNMENT/INDUSTRY WORKSHOP ON THE RELIAB--ETC(U)
DEC 78 W H LEWIS, W H SPROAT, W M PLESS F41608-76-D-A005
UNCLASSIFIED LG78ER0261 SA-ALC/MME-76-6-38-2 NL

4 OF 4
ADA
068223

END
DATE
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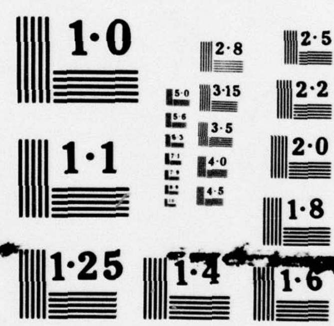
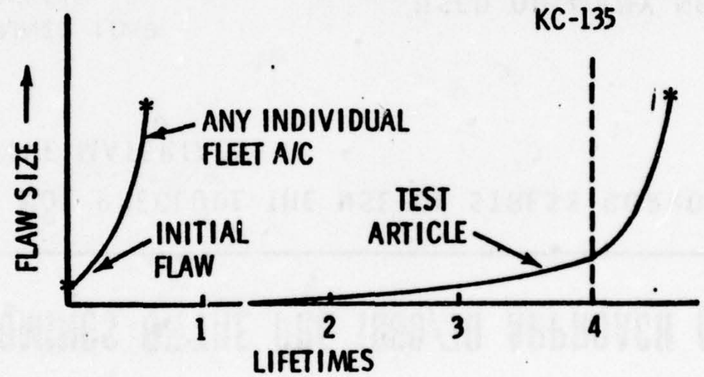


NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

SHORTCOMINGS OF THE PRE- 1969/70 AIR FORCE APPROACH

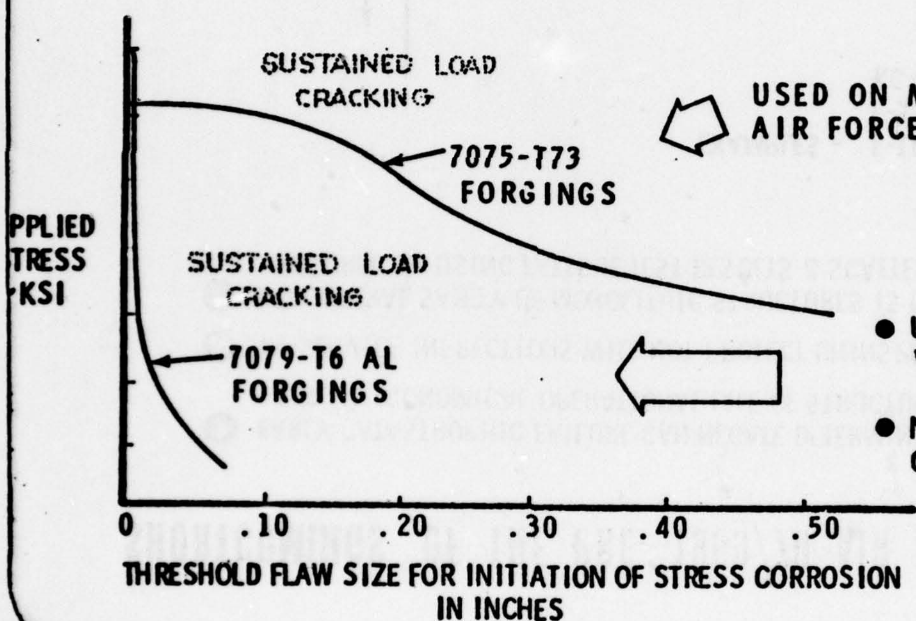
- EARLY CATASTROPHIC FAILURE CAN NEGATE DETERMINATION OF ACTUAL ECONOMICAL OPERATIONAL LIFE OF STRUCTURE
- IN-SERVICE INSPECTIONS WILL NOT PROTECT UNINSPECTABLE STRUCTURE
- STRUCTURAL SAFETY OF MONOLITHIC STRUCTURES IS NOT NECESSARILY ASSURED BY USING FATIGUE TEST RESULTS & SCATTER FACTOR OF 4

EXAMPLES - F-111 B-52
F-5
KC-135



SHORTCOMINGS OF THE PRE 1969/70 APPROACH (Cont'd)

- IT DID NOT PRECLUDE THE USE OF STRESS CORROSION SENSITIVE MATERIALS



USED ON MANY NEW AIR FORCE AIRCRAFT

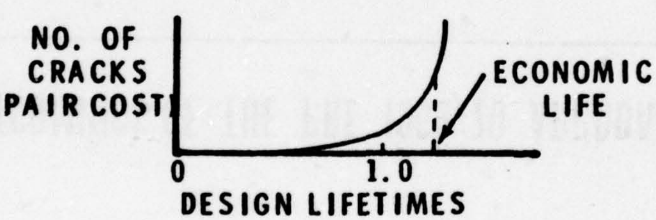
- USED ON MANY 1955-65 VINTAGE AIRCRAFT
- NUMEROUS IN-SERVICE CRACKING PROBLEMS
  F-4, T-38, 727, F-5, KC-135, 707, & OTHER

SHORTCOMINGS OF THE PRE 1969/70 APPROACH (Cont'd)

- IN ADDITION THE APPROACH:
  - LACKED ACCOUNTABILITY OF LOAD ORDERING EFFECTS
  - WAS OFTEN DEFICIENT IN CRITICAL AREA IDENTIFICATION (I.e. INSUFFICIENT POST TEST INSPECTION)
  - LACKED VISIBILITY OF CRACK GROWTH CHARACTERISTICS NECESSARY FOR AN ECONOMICAL AND EFFECTIVE FORCE MAINTENANCE PROGRAM
  - OFTEN RESULTED IN LATE TEST RESULTS AND THUS COSTLY RETROFITS

CURRENT MIL-STD 1530A APPROACH

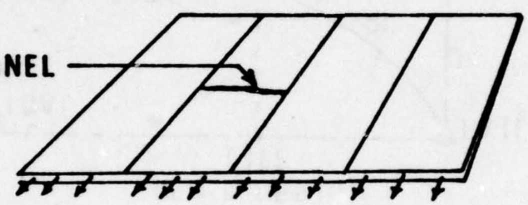
- GENERAL
  - THE "SAFE LIFE" APPROACH HAS BEEN ABANDONED & SAFETY & DURABILITY REQUIREMENTS DECOUPLED
  - SAFETY - AIRCRAFT WILL BE DESIGNED TO BE DAMAGE TOLERANT
    - FAIL-SAFE
      OR
    - SAFE CRACK GROWTH
  - DURABILITY - AIRCRAFT WILL BE DESIGNED SUCH THAT ECONOMIC LIFE > REQUIRED DESIGN LIFE



THE CURRENT MIL-STD 1530A APPROACH

- THE FAIL-SAFE DESIGN APPROACH:

  THE STRUCTURE IS DESIGNED SO AS TO CONTAIN A SINGLE MEMBER FAILURE WITHOUT LOSS OF AIRCRAFT



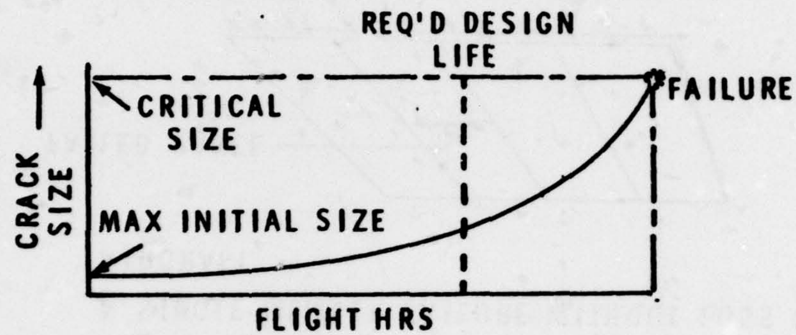
LIMITATIONS:

- REQUIRES EARLY DETECTION OF MEMBER FAILURE
- GENERALLY HEAVIER THAN SAFE CRACK GROWTH APPROACH
- FAIL-SAFETY DETERIORATES WITH ONSET OF ADJACENT MEMBER CRACKING (GENERALLY LATE IN LIFE)

THE CURRENT MIL-STD 1530A APPROACH (Cont'd)

- THE SAFE CRACK GROWTH DESIGN APPROACH:

  THE STRUCTURE IS DESIGNED (& INSPECTED) SO THAT THE MAXIMUM EXPECTED INITIAL DAMAGE WILL NOT GROW TO CRITICAL SIZE DURING SERVICE USE



LIMITATION:
SAFETY DEPENDENT ON:
- FRACTURE CONTROL PROGRAM TO ENSURE NO INITIAL FLAWS > SIZE ASSUMED IN DESIGN
- INDIVIDUAL AIRCRAFT TRACKING PROGRAM
- ACCURATE IDENTIFICATION OF FRACTURE CRITICAL AREAS

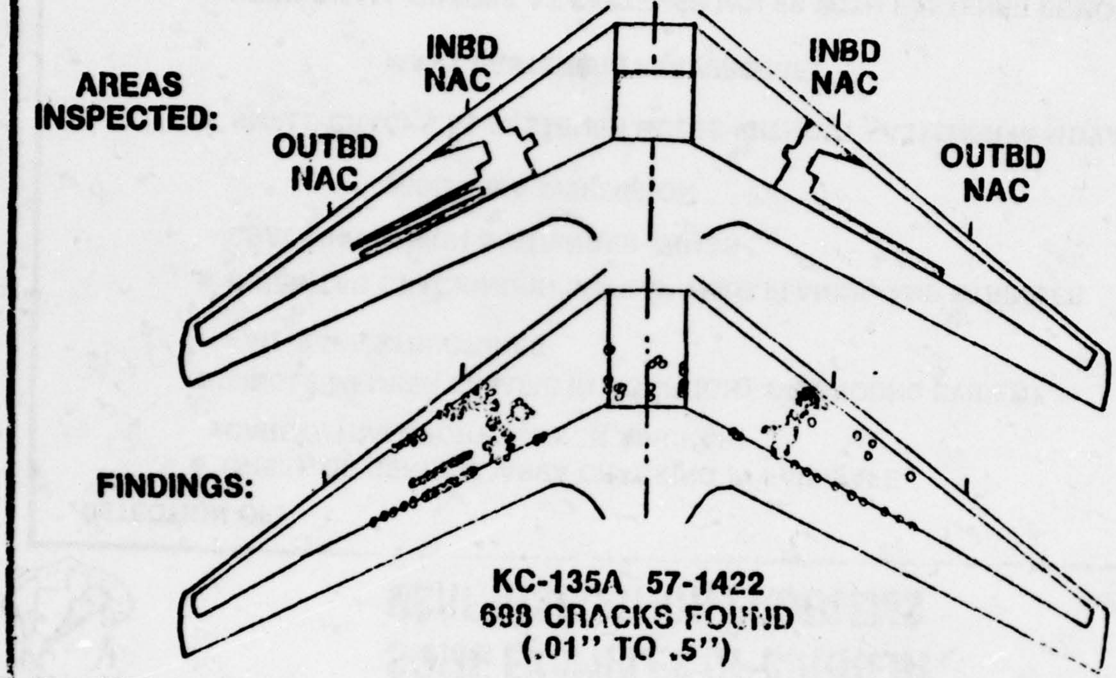
SOME EXAMPLES OF CURRENT USAF INSPECTION PROBLEMS

DETECTION OF:

- ONSET OF GENERAL AREA CRACKING IN FAIL-SAFE CARGO/TRANSPORT/TANKER AIRCRAFT
- SINGLE MEMBER FAILURE IN NONFLIGHT OR GROUND EVIDENT FAIL-SAFE STRUCTURES
- INNER TAB CRACKING IN SHIPLAP WING PLANKS, AND STRINGER CRACKING IN SKIN & STRINGER WINGS
  - WIDE AREA INSPECTION
- SMALL CRACKS AT FASTENER HOLES WITHOUT FASTENER REMOVAL
  - MANY FASTENERS PER AIRCRAFT
- VERY SMALL CRACKS AT FASTENER HOLES WITH FASTENER REMOVAL
  - FEW FASTENERS PER AIRCRAFT
- VERY SHALLOW SURFACE AND SMALL INTERNAL CRACKS AT SPECIFIC LOCATIONS IN GAS TURBINE ENGINE PARTS

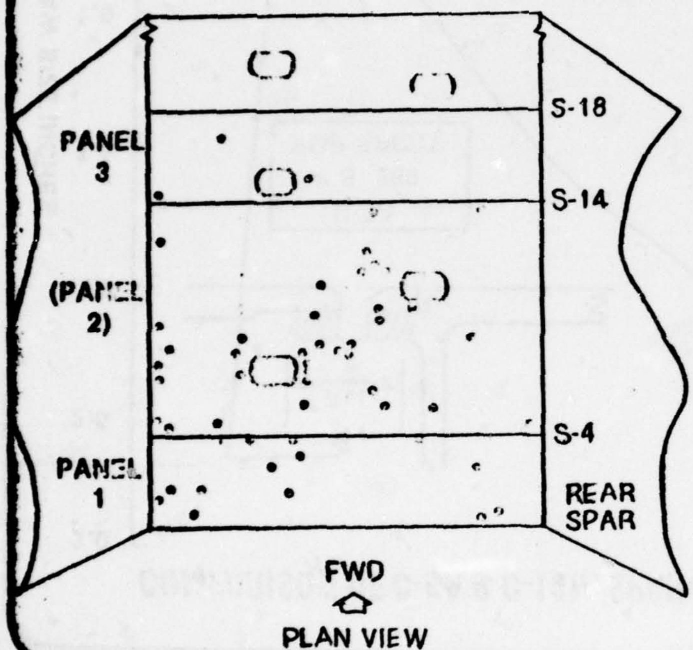
SUPPORTING EVIDENCE (CONT'D)

- RESULTS FROM TEAR DOWN INSPECTION OF SELECTED AREAS OF A WING AT APPROX. 11,500 TANKER HOURS



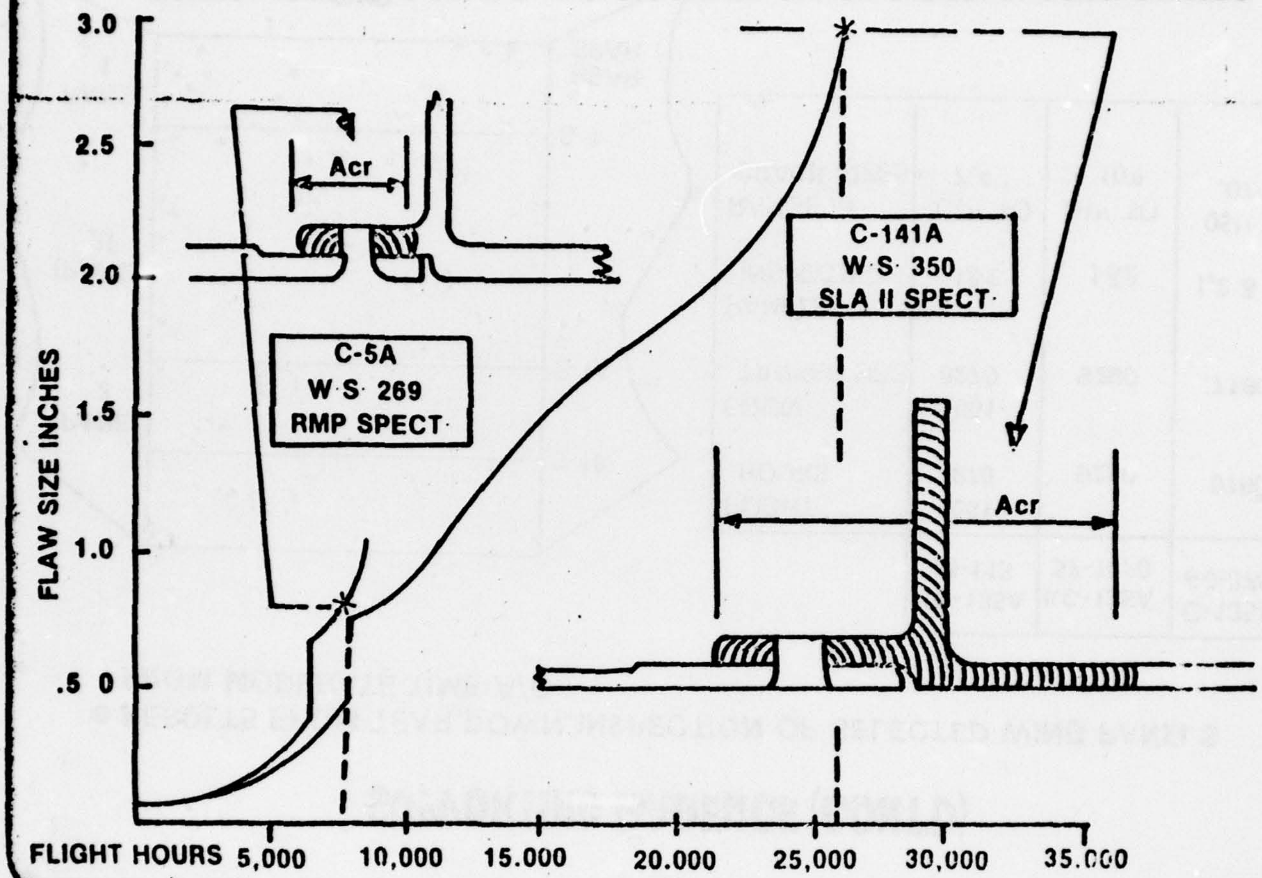
SUPPORTING EVIDENCE (CONT'D)

- RESULTS FROM TEAR DOWN INSPECTION OF SELECTED WING PANELS FROM MODERATE TIME A/C



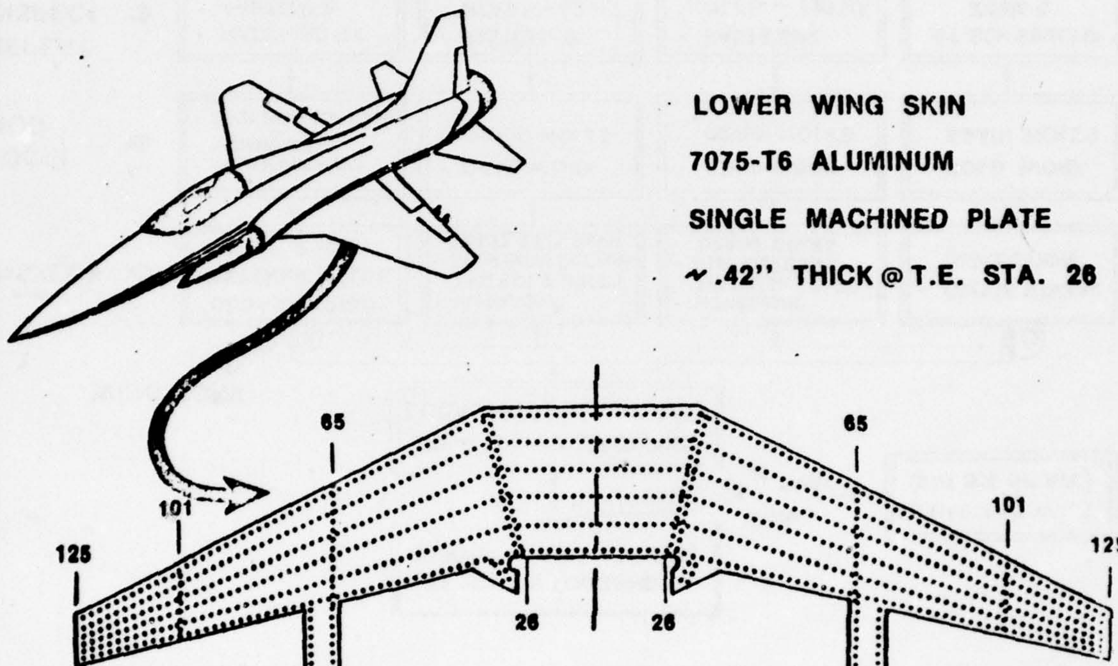
	KC-135A 58-113	KC-135A 57-1420	C-135A 60-378
FLIGHT HOURS	8061-8270	9280	9760
EQUIV. TANKER HRS	8061-8270	9280	:7190
PANELS INSPECTED	1&2	1&2	1,2 & 3
RANGE IN CRACK SIZES	.01" TO 7.4"	.01" TO > 10"	05" TO .07"

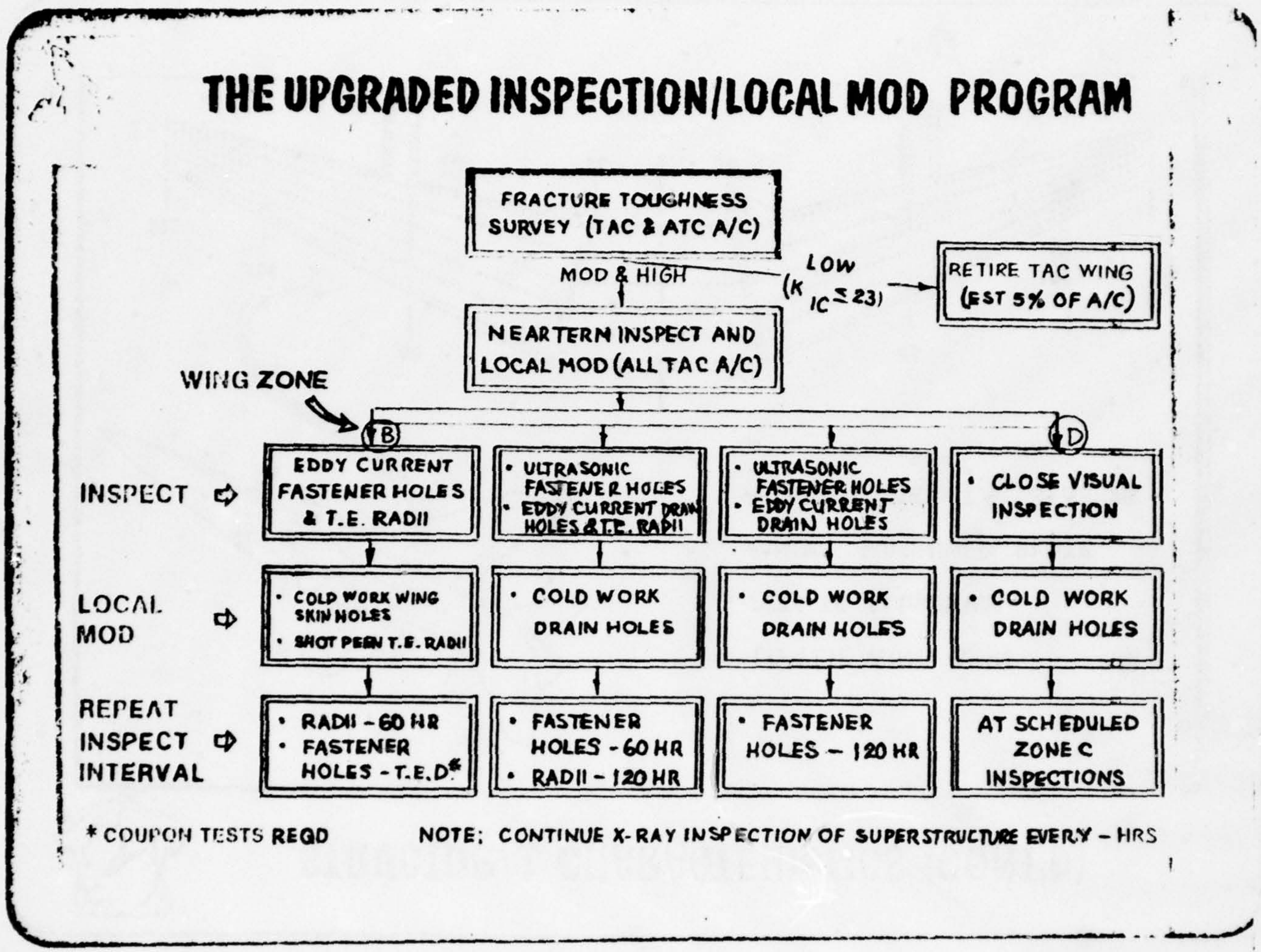
COMPARISON OF C-5A & C-141A SPANWISE SPLICE CRACK GROWTH CURVES



STRUCTURAL CHARACTERISTICS (CONT'D)

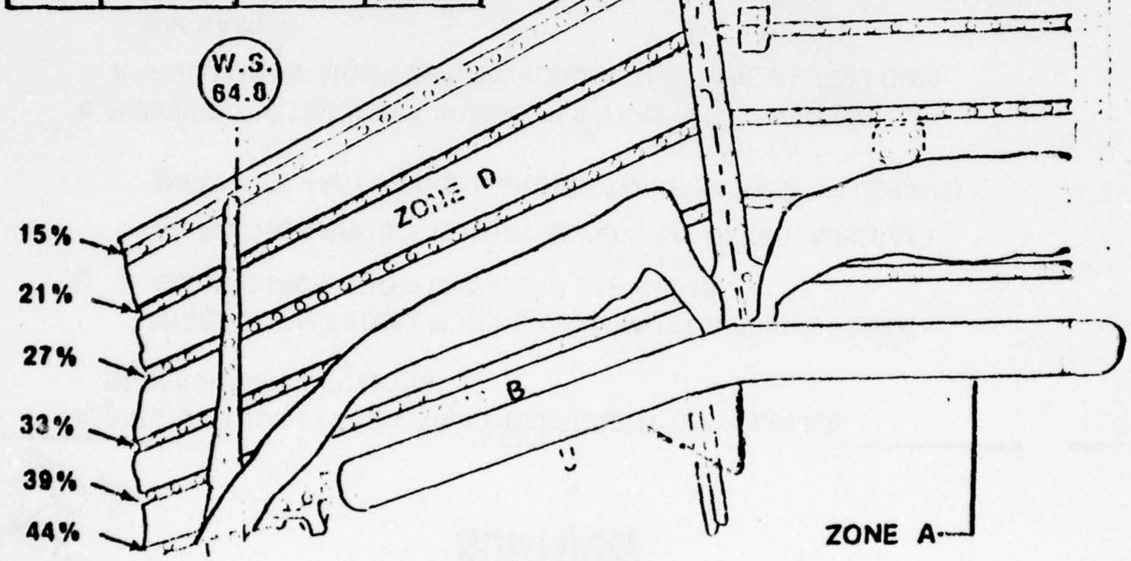
- LOWER WING SKIN
- 7075-T6 ALUMINUM
- SINGLE MACHINED PLATE
- ~.42'' THICK @ T.E. STA. 26




THE UPGRADED INSPECTION/LOCAL MOD PROGRAM
FRACTURE TOUGHNESS SURVEY (TAC & ATC A/C)
MOD & HIGH
LOW ($K_{IC} \leq 23$)
RETIRE TAC WING (EST 5% OF A/C)
NEARTERM INSPECT AND LOCAL MOD (ALL TAC A/C)
WING ZONE
B
D
INSPECT
EDDY CURRENT FASTENER HOLES & T.E. RADII
• ULTRASONIC FASTENER HOLES
• EDDY CURRENT DRAIN HOLES & T.E. RADII
• ULTRASONIC FASTENER HOLES
• EDDY CURRENT DRAIN HOLES
• CLOSE VISUAL INSPECTION
LOCAL MOD
• COLD WORK WING SKIN HOLES
• SHOT PEEN T.E. RADII
• COLD WORK DRAIN HOLES
• COLD WORK DRAIN HOLES
• COLD WORK DRAIN HOLES
REPEAT INSPECT INTERVAL
• RADII - 60 HR
• FASTENER HOLES - T.E.D*
• FASTENER HOLES - 60 HR
• RADII - 120 HR
• FASTENER HOLES - 120 HR
AT SCHEDULED ZONE C INSPECTIONS
* COUPON TESTS REQD
NOTE: CONTINUE X-RAY INSPECTION OF SUPERSTRUCTURE EVERY - HRS

WING LOWER SURFACE INSPECTION ZONES

ZONE	SAFETY LIMIT + AV.K[illegible]		INSPECT. INT.
	$a_i = .10$	$a_i = .20$	
A	85 HR	—	[illegible]
B	135 HR	5 HR	60 HR
C	250 HR	60 HR	120 HR
D	980 HR	640 HR	(VISUAL)



SUMMARY

- AIRCRAFT SAFETY IS VITALLY DEPENDENT ON RELIABLE IN-SERVICE INSPECTIONS
  - INSPECTION PROBLEM GENERALLY MOST DIFFICULT WITH SLOW CRACK GROWTH DESIGN CONCEPTS
  - INSPECTION PROBLEM MOST SEVERE ON OLDER AIRCRAFT (NEW AIRCRAFT BEING DESIGNED TO BE DAMAGE TOLERANT)

- REQUIRED DETECTION CAPABILITIES VARY WITH SPECIFIC APPLICATIONS, HOWEVER, TYPICALLY THEY ARE AS FOLLOWS:

  AIRFRAMES:
  - FASTENER HOLES (WITH FASTENER REMOVED) $\leq$.05'' CORNER
  - FASTENER HOLES (WITHOUT FASTENER REMOVED) $\sim$.10'' CORNER
  - INNER LAYER AND/OR INTERIOR STRINGERS $\sim$.20-.5'' THRU
  - AT FREE EDGES $\sim$.05'' CORNER

  HI-PERFORMANCE ENGINES:
  - SURFACE FLAWS $\leq$.01'' DEEP
  - INTERNAL FLAWS $\leq$.02'' DIA